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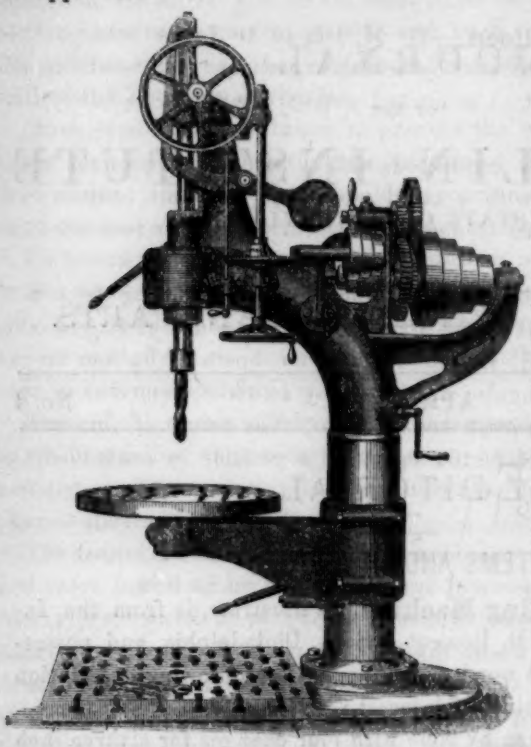
EDITORIAL.

ITEMS AND NOVELTIES.

The Upright Drilling Machine we illustrate, is from the Industrial Works of Wm. B. Bement & Sons, Philadelphia, and possesses a number of features worthy of notice. The following description will present the chief points of interest :

The machine is driven by cone with four changes for a three inch belt communicating with spindle by bevel gears. When increased power is desired, back gears are used, which are thrown into gear by an eccentric stud and also by a clutch pin, the head of which is visible at back end of outer cone bearing. The spindle is balanced, and is so arranged that it can be drawn through the whole distance of its traverse by one movement of a hand lever attached to balance lever stud. This is very convenient, as it facilitates the withdrawing of the drill and the clearing out of chips from a deep hole, and is also useful in starting a hole, as the hand lever is used altogether until the drill is ascertained to be cutting centrally. The machine has a self-feed, with three changes, also hand-feed. The self-feed is disconnected from the hand-feed by means of a clutch pin at the lower end of worm rod (under the hand wheel and not shown). When it is desired to use the hand lever for quick movement of spindle, the worm is disengaged

from the worm wheel by means of an upright rod with eccentric pin at upper end.



The table swings on its centre and around the column, by which means a piece can be drilled on any part of its surface without re-setting. In the lower part of the bracket holding the table, is a pin, which by being pushed into the heavy brass nut which supports the bracket, holds the table in a central position, and thus affords a bearing for a boring bar. The base plate can also be used for drilling or boring by swinging the table out of the way. The table is raised or lowered by screw and pinions inside the column. The drill is held in the spindle by friction, and is prevented from turning by a slot made to receive the upper end of shank.

The firm build four sizes of these machines, having the following capacities, viz: Distance from edge of column to centre of drill, 16 inches, 20 inches, 25 inches, and 30 inches.

A Magnetic Lock.—A lock of this description has been adopted, we are informed, in some of the English collieries, with a view to prevent miners and others employed in the collieries from opening their lamps with forged keys and other implements.

The lamps are self-locking, and cannot be opened save by aid of a powerful magnet, in the possession of the lamp-keeper. The invention is said to be applicable to any form of lamp, and to cost about a shilling. Any device by which the miner's lamp could be closed en-

tirely, except to some authorized person, would be a source of great safety.

A Navigable Balloon.—To M. Dupuy de Lome belongs the merit of having demonstrated by actual experiment the possibility of controlling (though but to a limited extent) the speed and direction of an air-ship.

The experiment was conducted with a balloon of peculiar construction (a large one with a small one inside to insure stability of form to the first), of an elongated shape, to offer least resistance to its motion.

The motive power, by which the question of increasing the speed of the vessel above that of the stratum of air in which it floated was successfully determined, consisted of a screw, operated by four men; while the directional impulse was given by a rudder formed of a triangular sail placed beneath the balloon. The height of this sail is 16 ft. 4 in. and its surface 161 sq. ft. Its position is controlled by two ropes, extending forward to the seat of the steerer.

The following comments, from Mr. John Wise, the librarian of the Institute, and perhaps the most experienced and accomplished of living aeronauts, may prove of interest in this connection:

"Dr. Solomon Andrews, of Perth Amboy, built an air-ship, which so far as the device to secure the stability of the float was concerned, was identical with that of De Lome's, about 15 years ago, but his motive power was intended to have been derived from gravitation. He had a rigid rim around the outer edge of the float, and the car with its weight was fixed to the balloon in such a manner that, by placing the weight at one end of it, it would be borne by the rigid rim, but when placed at the opposite end the weight would be borne by the elastic float, compressing the gas therein and causing the balloon to gravitate. By this alternation of compression and dilatation he would acquire momentum, and thus move forward in zigzag undulations, in the same way as the thistle-bird flies.

"But Andrews, like Dupuy de Lome, discovered by experience that when his vessel was afloat the wind would carry it along upon its current with very little deviation form its own course. If De Lome progressed 6 miles per hour faster than the breeze in which he floated, and was able to deviate 12 deg. to the right or left of his current line, he may flatter himself that he has taken all out of the navigable balloon that there is in it, as a machine dependent upon rudder and propeller. We may safely say this much for his air-ship, that it is

the best contrived piece of aerial machinery of the balloon kind, fixed with propelling apparatus, that has thus far been devised.

"We claim, however, much more for the balloon than all that has been done by attempting to use it as a steam-ship is used, *i. e.*, with wheels and rudder. As a drifting machine, with compensating appliances to regulate its altitude without the loss of gas or ballast, we can use it to sail to any part of the world. The balance-rope, as suggested by Baldwin and first used by Greene, is all the machinery necessary to enable us to go whither we desire. The trade winds give us the line of direction, and by a little barometrical experience we may soon learn to track the highways of the atmosphere, in order to travel to our points of destination with as much accuracy as does the mariner.

"Practical aeronauts have long ago learned that the balloon must find its use in another direction than that of imitating the water craft."

The Gardner Fire-Extinguisher.—The machine of which an exterior and sectional view are appended, is identical in principle of operation to the numerous extinguishers already known to the readers of the Journal, but differs in several details of construction involving the questions of convenience and efficiency.

Fig. 1.

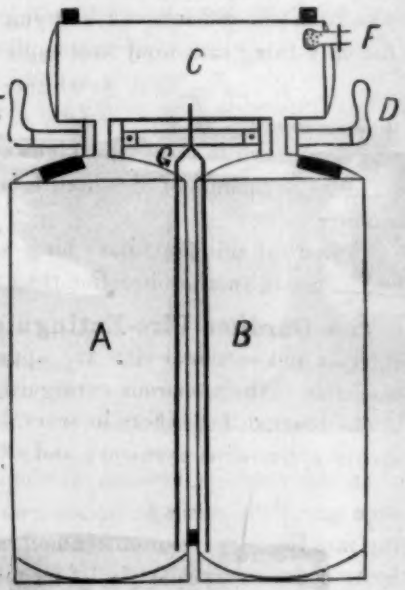
The main feature of the apparatus, which was described at a recent meeting of the Institute, resides in the fact that the acid and carbonate are kept in separate chambers, and that the gas is generated in a third chamber, from which it is delivered.

By keeping the ingredients in separate reservoirs until it is desired to utilize them, it is claimed, and we believe justly, that there will be less liability of an accident occurring to render the charge worthless; while by generating the gas in a special chamber, the stream is retained un-

der perfect control, and can be checked when one-fourth, one-half, or any portion of the charge is expended, the remainder serving for a future occasion. This is, without doubt, a valuable feature, in point of cleanliness, economy, and wear upon the apparatus.

Fig. 1 gives an exterior view of the apparatus in position for use. In fig. 2 the interior arrangement is visible. A and B are respectively the chambers for storing acid and carbonate. These chambers connect with a horizontal reservoir, C, the passages thereto being controlled by turning either of the handles, D or E. F is the delivery pipe for the gas, while G is a branching pipe, open above and below, by which the pressure in the gas chamber is transmitted to the liquids in A and B, and their equable flow into C is assured. The charge of acid and carbonate is made in their equivalent proportions, so that when consumed neither shall be in excess.

Fig. 2.

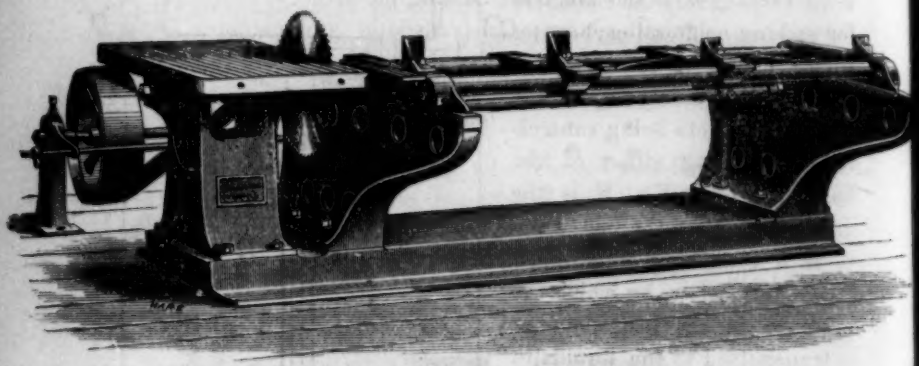


The reservoirs are built of lead-lined copper, and the cocks are made of lead-bronze, to resist chemical action. When not in use, the apparatus is, as shown in fig. 2, set away bottom uppermost, by which the liquids are kept from contact with the cocks and mechanical arrangements.

The apparatus seems to us to be well worthy of commendation, inasmuch as it combines all the good qualities of other machines with the special advantages of greater convenience of form, security of the cocks from the action of the materials employed, and of the perfect control of the stream of gas.

While believing that some misapprehension exists as to the true cause of the efficiency of this and similar gas-generating machines (a question which is now being tested by the Institute Committee on Science and the Arts), we can endorse this form, as the most practical of any yet made public.

Carriage Cutting-off and Squaring Machine.—The accompanying figure shows a perspective elevation of a machine of this kind, built for the New Haven and Northampton Railway Company by Richards, London & Kelley, of this city. The arrangement is novel in several respects. The carriage, which is fed by hand, is carried on rollers, a plan that has often been attempted without success from the difficulty of keeeping it "square," the V track being the only thing that would accomplish the purpose.



In this machine, however, this object is secured by means of a shaft, seen under the carriage, on each end of which there is a pinion gearing into the rack, seen on the end rails of the carriage. These pinions being connected positively by means of the shaft, of course produce a coincident movement of each end of the carriage without offering the least resistance.

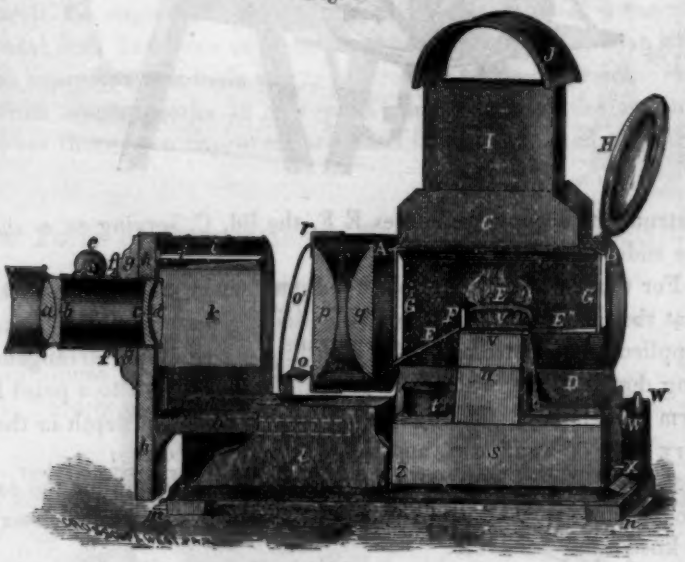
This device was employed some years since for a similar purpose in the Reading Railroad Company's works, at Reading, Pa., and is one of those simple and at the same time important things the importance of which bears an inverse ratio to its ingenuity, and involve the true principle of improvement in machines.

The cross rails on the carriage slide to any point on the cylindrical rails, and have spring stops or gauges to regulate lengths. The longitudinal rails are of wrought iron tubing, for lightness. All parts of the framing are made with corner section, including the heavy sole plate. We regret that the engraving is not in true elevation, but the detail is of such a character, and the parts fall so near in one horizontal plane, that the perspective view conveys a more complete idea, if not so correct a one, as a true drawing. The scale approximates $\frac{1}{2}'' = 1'$.

The Sciopticon.—This instrument, which is a very efficient form of magic-lantern, using a lamp in place of the lime light, has had a previous notice in this Journal, but has since received a number of minor improvements, which render it extremely convenient for use in schools or elsewhere where the oxy-calcium light is not to be obtained. Its effects are very satisfactory.

The illustration gives a view of the essential portions of the apparatus in section. *a b c d* are the lenses of objective, *p g* those of condenser; *o o'* is the stage for holding pictures; *s*, lamp cup; *w w*, buttons for regulating lamp; C I, ventilator and chimney; and H, reflector.

Fig. 1.



The necessity of having some form of the lantern, for object illustration, which should furnish a good illumination without the several inconveniences attendant upon the oxy-hydrogen light, is severely felt in many localities remote from cities, and even in these when the means or skill to operate the latter is wanting or troublesome to obtain. For such cases Mr. Marcy's compact and portable apparatus affords an admirable substitute, which we have no hesitation in recommending for simplicity, convenience and performance. Fig. 2 shows the stand and position of lanterns when used for dissolving views. When taken down the legs swing together on their hinges, and the

Fig. 2.

instruments occupy the spaces E F, the lid, C, serving as a shelf for the slides.

For those who have not observed our former notice, it may be said that the lamp, which is the distinguishing feature of the lantern, is supplied with petroleum oil, affording, by a simple arrangement, a long double flame, which is concentrated and drawn to a point by the form of chimney. The light is about two inches in depth in the ordinary form of apparatus, and is of extreme whiteness.

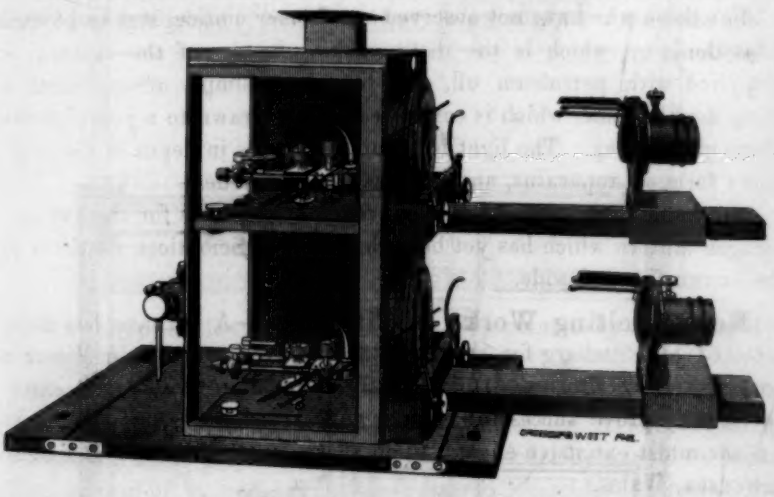
As the most satisfactory and convenient substitute for the oxy-hydrogen lantern which has yet been devised, the Sciopticon deserves to be known far and wide.

New Smelting Works at Pittsburg.—A furnace has been erected at Pittsburg for the smelting of silver ores of our Western States and Territories. It is greatly to be desired that this enterprise may prove successful enough to warrant the growth of works in our midst extensive enough to do all the work which now is done in Swansea, Wales.

The favorable situation of that city, from its direct railroad connections with the West, and the immediate vicinity of cheap fuel of excellent quality, point to it as the proper position for the inauguration of this enterprise.

Improvement of the Ohio River.—Those interested in this important measure and the engineers having it in charge, at a recent convention held in Cincinnati, after a discussion of the various plans of river improvement, have made a report, in which it is claimed that any system which would secure a channel depth of six feet throughout the year, would so enhance the value of property, increase population, multiply cities along its shores, and so cheapen the primary comforts of life that the question of cost should be a secondary consideration. As to the best method, they say that Congress should authorize an elaborate examination by competent engineers of the whole subject of river improvement in this country, testing the comparative merits of different systems. In relation to the work thus far finished, Col. W. E. Morrell, the engineer in charge, announced that much of it was experimental, and has done as much harm as good. The opinion was likewise expressed that little was to be profited by the experience derived from similar works in European countries, since the streams which have there been improved are small in size compared with the Ohio.

New Form of Stereopticon.—The accompanying engraving



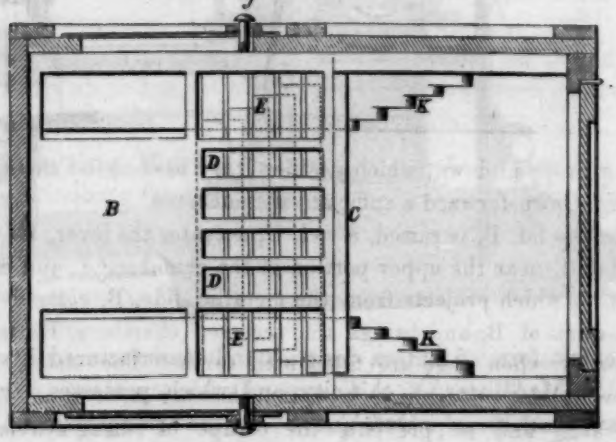
represents a form of lantern designed and manufactured by the firm of W. M. McAllister, of this city, and which possesses, for certain purposes, a number of conveniences. In the arrangement of lanterns one above the other for dissolving views much less space is occupied,

and the management of the lights rendered less troublesome than where the two are arranged side by side, as in the ordinary plan, since here both may be observed at once. The proper angleing of the lenses is accomplished by attaching both condensers with objective stands to the box in such a manner as to admit of motion in a vertical direction. The rods projecting through the front of box, connect with a pawl and rachet movement, by which the limes are turned at the insertion of each picture, thus dispensing with the cumbersome clockwork generally relied upon to do this work. The heating of the interior of box is avoided by the interposition of an air-space beneath the horizontal partition, the chimney being at the side. The apparatus is very complete, and being compact in form, is well adapted for school or exhibition purposes.

Wakefield Earth Closet.—The accompanying cuts represent horizontal and vertical sections of this contrivance. It is unnecessary for us to enter into the discussion of the merits of the earth closet system, or to present its great advantages, sanitarily, economically and æsthetically, for these matters have been decided long ago by the strongest endorsements of the chemist and physician.

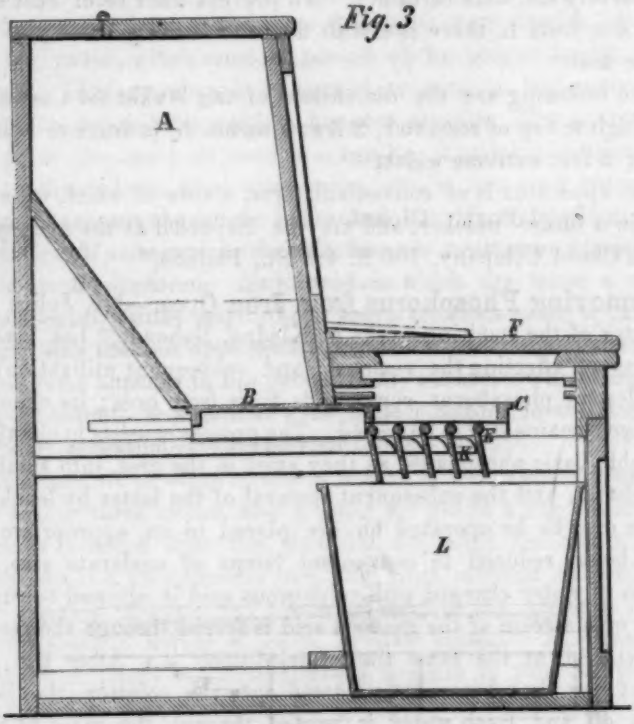
The following notice is a simple description of the construction of the machine. Figures 2 and 3 are respectively horizontal and vertical sections.

Fig. 2



A shows a reservoir for the reception of the earth (charcoal or other absorbent.) At the bottom of this chamber is placed a metallic slide, B, and when the commode is not in use this slide is drawn forward, as seen in Fig. 3, and forms a bottom to the chamber, A, fitting close to its edges. The front portion of this slide, as shown at C, consists of shallow chambers, D, which are recessed, and are closed by means of the pivoted slats as shown at E. In Fig. 3 these slats are shown

Fig. 3



as being dropped down, which position they assume by their gravity on being drawn forward a sufficient distance.

When the lid, F, is raised, a rod, G, actuates the lever, H, which is pivoted at I, near the upper portion of the chamber, A, and engaging the pin, J, which projects from the metallic slide, B, compels a backward motion of B, and brings the recessed chambers, D, under the chamber, A, when they are filled with earth. The slide, N, serves to close the slat underneath it in the chamber A, in which the pin, J, operates, and so prevents the escape of disagreeable odors. Earth is retained in the chambers, D, by the closing of the slats, E,

which are raised by becoming engaged with the steps, K, as the seat, F, is raised.

In closing the lid, a reverse of the movement described takes place. By the forward action of the rods, G and H, and the stud, J, the plate, B, is thrown forward, the slats, E, become disengaged from the steps, C, drop down, and the contents of the shallow recesses or chambers, D, are discharged into the bucket, L, covering its contents completely and with certainty. To prevent the rise of dust or offensive odor from L, there is a slide made to entirely close the opening in the seat.

The following are the dimensions of the Wakefield Commodes: 3 feet high to top of reservoir, 2 feet 7 inches from front to rear on the floor; 2 feet extreme width.

The apparatus is of convenient form, a view of which we will present in a future number, and may be inspected at the agency of the Earth Closet Company, 105 S. 4th St., Philada.

Removing Phosphorus from Iron Ores.—Mr. Julius Jacobi, Director of the smelting works at Kladno, Bohemia,* has invented a process of effecting the removal (and subsequent utilization) of the troublesome phosphorus compounds from iron ores; its efficiency in practice remains still to be tested. The process consists in changing the insoluble basic phosphates, as they exist in the ores, into soluble acid phosphates, and the subsequent removal of the latter by leaching.

The ores to be operated on are placed in an appropriate vessel, after being reduced to convenient lumps of moderate size, and a stream of water charged with sulphurous acid is allowed to run upon them, or a stream of the gaseous acid is forced through the mass, and cold water is at the same time turned upon it. After the greater part of the phosphates have passed into the solution, the liquid is drawn off, and fresh water is passed through the mass to wash it thoroughly—this operation being continued as long as phosphoric acid can be detected in the wash water. If much phosphorus exists in the ores, the operation with sulphurous acid must be repeated, until a sufficient degree of purity is reached.

The liquid containing the acid phosphates is heated to drive off the sulphurous acid, and the phosphates are again separated, partially by concentration, or by precipitation with lime. This being a valuable fertilizer, is relied upon to cover a large portion of the expense of the operation.

* Bai. Ind. u Gewerbe Blatt.

Sensitive Flames. By Isaac Norris, M.D.—The arrangement of Barry for rendering a flame sensitive is well known, and offers the great advantage of using the gas at the ordinary pressure, so that the experiment is arranged in a moment. The size of the pin-hole aperture determines the height of the flame burned above the wire gauze. I have found after many experiments that it is rendered much more sensitive by using a chimney,—an ordinary glass one, such as employed with the argand burner, answering perfectly and rendering the flame at the same time much more steady. It may rest on the gauze, which must be placed at the proper height above the burner. The gas should be burned on until it begins to flare, and then lowered a little until it becomes steady. The nearer it is to this point the more delicate the result. Tyndall's caution with regard to obstructions from stop cocks, etc., is also very important. Wishing to measure the height I attached a small scale to the chimney, and found, as recorded, that the flame is much more sensitive to some sounds than others. Any sound in which the letter s enters seems to affect it particularly. Attaching a telescope to the apparatus, something like the arrangement in a cathetometer, I found that even when the flame appears to the eye perfectly steady, it was continually varying in height—sounds that were quite inaudible to any one near it, evidently producing a marked result.

A tall flame, six or eight inches in height, is not as sensitive as one of only two or three inches, and placing the gas in a bag at the same pressure as it issues from the pipe did not alter the result. The whole subject is a very curious one, and I am inclined to think this flame is *the most delicate* yet produced, despite the accounts of the wonderful steatite burner of which Tyndall speaks. An illustrated description of Barry's sensitive flame appears in this Journal for January, and it is to be hoped the present little article may lead to other experiments in the same direction.

A New Hygrometer.—Mr. W. G. Whitehouse has communicated to the Royal Society a description of an instrument of this kind, of which the following is a short account:

It consists essentially of three thermometers of similar construction and used as a wet bulb, a dry bulb and an acid bulb respectively, placed conveniently side by side on a frame, and read together for comparison.

The acid bulb is arranged so that a regulated supply of strong sulphuric acid, free from lead and of uniform density, shall flow upon

the bulb (say about one drop per minute). This is accomplished by using a capillary siphon tube, properly adjusted for the delivery of the needful supply.

The action of the acid is to condense upon the bulb the moisture of the air, and to set free a certain amount of heat, dependent upon the quantity of moisture in the atmosphere, upon it, causing an elevation of the temperature. This elevation in temperature is strictly a measure of the amount of moisture in the air absorbed by the acid film spread upon the surface of bulb. The supply of concentrated acid is constant, as the hydrated acid passes off.

This form of instrument is identical in principle with the wet and dry bulb, the measurement being in either case a thermometrical one; but in the ordinary instrument the zero of the scale is reached in an atmosphere saturated with moisture, and its action depends upon the heat rendered latent by the evaporation from its surface; while the acid bulb thermometer is at its zero in a perfectly dry atmosphere, and depends for its action upon the amount of sensible heat evolved by condensation of water vapor on its surface and the heat generated by its combination with the acid. The instrument is pronounced to be of extreme delicacy.

Carburetted Air in Iron Manufacture.—It is stated that in certain smelting establishments in Europe, the experiment is being tried, and with success, of using air carburetted by passing over petroleum in the reduction of iron from its ores.

Measurement of Stellar Motion by the Spectroscope.—A very beautiful *acoustic* illustration of the method of determining stellar motions by the spectroscope was lately given by Prof. A. M. Mayer, in a lecture at the Sheffield Scientific School, which in its extreme simplicity is worthy of admiration.

The lecturer explained the effect of lengthening or shortening a wave, stating that in the case of a sound-wave (all of them moving at the same velocity), if the length be diminished, more vibrations enter the ear in a given time, and the pitch is raised; the reverse takes place on increasing the length. The lecturer then dwelt upon the analogy between the sound waves and those of light. Hence, whenever one of the colored waves composing white light is lengthened, its color is modified in the direction of the red end of the spectrum, and *vice versa*. The motions of a star when at right angles to the view is susceptible of telescopic measurement, but, the lecturer continued,

the motion of a star when in the direction of the line of sight can only be measured on the principle above named, the standard being the displacement from their normal position of certain lines in its spectrum. This principle the lecturer proceeded to illustrate by means of sound waves. With the lantern the image of a tuning fork beating 256 times a second—and giving a certain note—was thrown on the screen. By the side of one of the prongs, and just touching it, was a carefully rounded and varnished cork ball, suspended by a filament of silk. On sounding a second fork placed on its case and tuned in accurate unison with the first (by an ingenious method devised by Prof. Mayer) anywhere in the room, even 30 feet distant, the first was thrown into vibration and the image of the cork ball was projected a foot or two away from the prong. When, however, the second fork was sounded, and the lecturer walked rapidly—at a rate of 8 feet a second—towards or from the first, touching the case only when in motion, no motion of the cork was observed, the wave being in this way shortened or lengthened by an amount sufficient to throw it out of unison with the lantern fork. Again, a third fork, vibrating 254 times a second, produced no effect on the ball; but when sounded and placed on its case as this was swung rapidly toward the first fork, the wave length was thereby so shortened as to bring it into unison with this, and the ball promptly responded. A fourth fork, vibrating 258 times, showed the same phenomenon when placed on its case, as this swung away from the first fork, the wave thus being shortened into unison. The demonstration was most complete and satisfactory.

New Method of Obtaining Potassium.*—Prof. A. E. Dalbear describes a process for obtaining the metals potassium and sodium, which may prove, if properly tested, of commercial value. The sulphide of potassium was formed by treating dissolved sticks of caustic potash with sulphuretted hydrogen, and subsequently evaporating until the mass was solid on cooling. This mass was then mixed with somewhat more than its bulk of iron filings and subjected to distillation, the product being led into petroleum. The products used in the operation are cheap, and the process seems to be a very sensible one, and worthy of trial on the commercial scale.

Permanency of Photographic Silver-prints.—Our photographic contemporaries contain a communication upon this subject from Mr. Carey Lea, in which the author declares, that of a number

* Amer. Chemist ii. 297.

of photographic prints, toned by various processes, all of them, after being kept for seven years, proved to be permanent. The opinion is ventured that when silver prints turn yellow, the fault is to be ascribed to careless treatment, either in the introduction of too many pictures in small quantity of the fixing bath, or in imperfect washing; in either case the fault of the operator.

Products of the Explosion of Nitro-Glycerin.—M. L. L'Hote announces to the French Academy the following method of determining the character and relative proportions of the products formed in the explosion of nitro-glycerin.

The author substituted for the blow of the hammer, the blow produced by the explosion of a mixture of hydrogen and oxygen. A eudiometer tube of thick glass was supplied with a measured quantity of the explosive mixture (H and O), and a weighed quantity of the nitro-glycerin was inserted. The method adopted was to insert the material by a capillary tube into a very small bulb of thin glass, and to bring this, after careful weighing, up into the eudiometer. The passage of the spark and the shock of the combustion of the mixed gases, caused the explosion of the nitro-glycerin, and the breaking of the thin glass bulb. The products of the explosion collected in the tube could then be treated as in an ordinary gas analysis. By this method one gramme of nitro-glycerin was found to produce: 284 c. centm. of gas. Analysis by absorption showed this to consist, in 100 parts, of

Carbonic acid, ...	45·72 vols.
Nitric Oxide, ...	20·36 "
Nitrogen, ...	33·92 "
	100.00.

An Acoustic Experiment.—Let a wide glass tube, open at both ends, be taken, and in this a piece of fine wire gauze be pushed up some little distance. If the gauze is now heated to redness over an ordinary Bunsen burner, and then removed, it will shortly emit a shrill note, lasting from 5—10 seconds. The experiment we believe will be new to most of our readers, and has the merit of always going off. The author has not been named to us. Rijke

EASTWICK and HARRISON'S LOCOMOTIVE.
MANUFACTURED AT THEIR WORKS, TWELFTH AND WILLOW STREET RAILROAD.

EASTWICK and HARRISON'S LOCOMOTIVE.

MANUFACTURED AT THEIR WORKS, TWELFTH AND WILLOW STREET RAILROAD.

PHILAD'A, 1848.

Civil and Mechanical Engineering.

THE LOCOMOTIVE ENGINE, AND PHILADELPHIA'S SHARE IN ITS EARLY IMPROVEMENTS.

By Joseph Harrison, Jr., M. E.

(Continued from page 174.)

Philadelphia mechanics, following the lead of their predecessors in the same field, entered with zeal into the Baltimore contest. An engine was built by a Mr. Childs, who had invented a rotary engine which in a small model promised good results, and an engine of about fifty horse-power on this rotary plan was built and sent to Baltimore for trial. A record of its performance cannot now be easily reached, but it is known that it was never heard of as a practically useful engine after this time.

The second locomotive built in Philadelphia, to compete at Baltimore, was designed by Mr. Stacey Costell, a man of great originality as a mechanic, and the inventor of a novelty in the shape of a vibrating cylinder steam engine, that had some reputation in its day, and has come down to our time in the little engine now sold in the toy shops for a dollar. The Costell locomotive had four connected driving wheels, of about thirty-six inches in diameter, with two six-inch cylinders of twelve-inch stroke. The cylinders were attached to right-angled cranks on the ends of a counter shaft, from which shaft spur gearing connected with one of the axles. The boiler was of the Cornish type, with fire inside of an internal straight flue. Behind the bridge wall of this boiler, and inside the flue, water tubes, were placed at intervals, crossing each other after the manner of the English Galloway boiler of the present day. The peculiar arrangement of this engine made it possible to use a very simple and efficient mode of reversement by the use of a disc between the steam pipe and the cylinders, arranged with certain openings, which changed the direction of the steam and exhaust by the movement of this disc against a face on the steam pipe near the cylinder, something after the manner of a two-way cock. It is not known whether this locomotive of Costell went to Baltimore or not. It is known, however, to have been tried on the Columbia road in 1843 or 1844, but its success was not very striking, and it was subsequently broken up. The boiler of the

Costell locomotive had very good steam-making qualities. It was used for a long time as a stationary engine boiler.

The third engine begun in Philadelphia for the Baltimore trial was after a design of Mr. Thos. Holloway, an engineer of some reputation forty years ago as a builder of river steamboat engines. This engine was put in hand, but never was completed.

Something was gained even by the failures that are here related, and these early self-reliant efforts show with what tenacity Philadelphia engineers clung to their early idea of building an original locomotive, and it will be seen hereafter that a type of locomotive essentially American was ultimately the result.

Whilst these movements towards the improvement of the locomotive were going on amongst us, the desire to have the railroad in every section of the country became more and more fully confirmed. The railway from New-castle to Frenchtown, sixteen miles in length, was finished in the winter of 1831 and 1832, and two locomotives, built by Robert Stephenson at Newcastle-upon-Tyne, were imported to be run upon this line, which made then an important link in the chain of passenger travel between New York and Washington. In this case, as in several others in the early history of the railroad in the United States, this new element came in as an adjunct mainly of the river steamboats, and was considered most useful in superseding the old stage coach in connecting river to river, and bay to bay.

That the railway would supersede the steamboat for passenger travel, and the canal for heavy transport, was not dreamed of in the early day of the new power.

When the English locomotives were landed at New-castle, Delaware, it became necessary to select a skilled mechanic to put them together as speedily as possible. Through the agency of Mr. Wm. D. Lewis, a most active Director of the Newcastle and Frenchtown Railroad Company, this task was assigned to Matthias W. Baldwin. These engines were of the most improved English type, and greatly superior to any that had then been made in this country. In putting these engines together Mr. Baldwin had all the advantage of handling their parts and studying their proportions, and in making drawings therefrom. This proved of great service to him when he received an order, in the Spring of 1832, to build a locomotive for the Philadelphia, Germantown and Norristown Railroad. This engine, called, when finished, the "Ironsides," was placed upon the above road in November, 1832, and proved a de-

cided success. Mr. Franklin Peale, in an obituary notice of M. W. Baldwin, writes, "that the experiments made with the 'Ironsides' were eminently successful, realizing the sensation of a flight through the air of fifty or sixty miles an hour." The "Ironsides," in its general arrangement, was a pretty close copy of the English engines on the New-castle and Frenchtown Railroad, but with changes that were real improvements. The reversing gear was a novelty in the locomotive, although the same mode had been long used for steam ferry boats on the Delaware. This arrangement consisted of a single excentric with a double latch excentric rod, gearing alternately on pins on the upper and lower ends of the arms of a rock shaft. This mode of reversing was used in the Baldwin locomotives for many years after the "Ironsides" was built. It is creditable to Mr. Baldwin as an engineer that the "Ironsides" was the first and last of his imitations of the English locomotives. He, following the bent of all the Philadelphia engineers and mechanics that had entered the field, aimed too, at making an American locomotive.

Following the success of this first locomotive, other orders soon flowed in upon Mr. Baldwin, and on these later engines many valuable improvements were introduced, of which mention will be made hereafter. Col. Stephen H. Long, nothing daunted or discouraged by the unsuccessful results of his first engine in 1831, renewed his efforts, and under the firm of Long and Norris, the successors of the American Steam Carriage Company, commenced building a locomotive in 1832, subsequently called the "Black Hawk." This engine, when finished, was run for some time on the Philadelphia and Germantown Railroad, and did good service in the summer of 1833, in competition with Baldwin's "Ironsides." The "Black Hawk" burnt anthracite coal with some success, using the natural draft only, which was increased by the use of a very high chimney, arranged to lower from an altitude of at least twenty feet from the rails, to a height which enabled it to go under the bridges crossing the railroad. In all of Col. Long's experiments he seems to have discarded the steam jet, or exhaust, for exciting the fire. The "Black Hawk" had several striking peculiarities beside the one just mentioned. The boiler was unlike any that had preceded it, in having the fire-box arranged without a roof, being merely formed of water sides, and in being made in a detached piece from the waist or cylindrical part. The cylinder portion of the boiler was made up of two distinct cylinders, about twenty inches in diameter, and these lying close together, were bolted to the rear

waterside and thus covered the open top, and their lower half-diameters thereby became the roof of the fire-box. A notch was cut half way through these two cylinders on their lower half diameters about midway of the length of the fire-box, directly over the fire, and from these notches flues of about two inches diameter passed through the water space of each cylinder portion of the boiler to the smoke-box. These flues were seven or eight feet in length. Besides passing through the flues, the fire passed also under the lower halves of the cylinder portions of the boiler, a double sheet iron casing filled between with clay, forming the lower portion of the flue and connecting it with the smoke-box.

The "Black Hawk" rested on four wheels, the driving wheels about four and a half feet diameter, being in front of the fire-box. The guide wheels were about three feet diameter. Inside cylinders were used, and these required a double crank axle, and the latter, forged solid, could not easily be had. Col. Long overcame this difficulty by making his driving axle in three pieces, with two bearings on each, and with separate cranks keyed on to the ends of each portion of the axle, with shackle or crank pins arranged after the manner of the modern side-wheel steamer shafts. Flanged tires of wrought iron could not then be had easily, and this was overcome in the "Black Hawk," by making the tread for the wheels of two narrow bands, shrunk side by side on the wooden rim, with a flat ring, forming the flange, bolted on the side of the wheel. Springs were only admissable over the front axle, and to save shocks in the rear, the after or fire-box portion of the boiler was suspended upon springs. The Camb cut-off, then much in vogue on the engines of the Mississippi steamers, was used in the "Black Hawk." With some slight alterations this locomotive was sent to a road in New England in 1834. Other locomotives, mainly after the design of the "Black Hawk," were built by Long & Norris, and by William Norris & Co., in 1834, but they were not greatly successful. With the firm of William Norris & Co. Col. Long retired from the manufacture of locomotives in Philadelphia, and his name was not thereafter heard of in connection with its improvement. On the retirement of Col. Long, William Norris, a gentleman then with no acknowledged pretensions as a mechanic or engineer, brought other skill to his assistance, and after several not very successful efforts with engines of a design more like those that had succeeded of other makers, brought out an engine, in 1836, called the "George Washington," the success of which laid the foundation of the large

business done for thirty years thereafter at Bushhill, Philadelphia, by William Norris, and subsequently by his brother Richard Norris. The "George Washington" was a six-wheel engine with outside cylinders, having one pair of driving wheels, 4 feet in diameter, forward of the fire-box, with vibrating truck, for turning curves, in front. This engine weighed somewhat over fourteen thousand pounds, and a large proportion of the whole weight rested on the single pair of driving wheels. This locomotive, when put upon the Columbia road (now Pennsylvania Central), did, apparently, the impossible feat of running up the old inclined plane at Peter's Island, 2,800 feet long, with a rise of one foot in fourteen, drawing a load of more than nineteen thousand pounds above the weight of the engine, and this, too, at a speed of fifteen miles per hour. This was no doubt impossible, if the simple elements of the calculation are only considered. But there was a point in this experiment, well known to experts at the time, which *did* make it possible, even by calculation; and this point consisted in the amount of extra weight that was thrown upon the drivers by the action of the draft link connecting the tender with the engine,—the result being that about *all* the weight of the locomotive rested upon the drivers, less the weight of the truck frame and wheels in front. This most extraordinary feat, a writer on the subject says, "took the engineering world by storm, and was hardly credited." The "George Washington, an outcrop of the earlier efforts of Col. Long, was unquestionably a good and well made engine, and greatly superior to any that had preceded it from the Norris Works. The fame this engine earned led to large orders in the United States, and several locomotives of like character were ordered for England and for Germany.

Improvements were made from time to time in the Norris locomotives—the establishment fairly holding its own with its rivals until the Norris Works ceased to exist about1866 or '67. Mr. William Norris, the founder of the works at Philadelphia, at one time commenced the building of locomotives at Vienna, Austria, but with no very great success; and after his return ceased his connection with the Norris Works. At the epoch from 1833 to 1836, the Norris and Baldwin engines had each their advantages and defects.

"The Norris engine, as it was at the commencement of 1837, may be described as follows: The boiler was of the dome pattern, known in England as Bury's, and used by that maker in 1830; the framing was of wrought iron, the first made entirely of this material in this country; the cylinders were placed outside of, and were fastened

to the smoke-box as well as to the frame. The engine was supported on one pair of driving wheels, placed forward of the fire-box, and on a swivelling four-wheeled truck placed under the smoke-box. The centre of the truck being so much in advance of the point of bearing of the leading wheels in the English engines of that day, there was considerably greater weight placed upon the driving wheels in proportion to the whole weight, while it was not unusual to adjust the draw bar so as to throw a portion of the weight of the tender upon the hinder end of the engine when drawing its load. This engine used four excentrics with latches. Hand levers were used for putting the valve rods into gear when standing. The valve motion was efficient, as the performances of these engines fully attested."

The "Baldwin" engine of the same period had a similar boiler, and somewhat similar position of, and fastening of the cylinders. The driving wheels were placed behind the fire-box, the usual truck being placed under the smoke-box. These engines ran steadily, owing to their extended wheel base, although they did not have the weight on the drivers, and the consequent adhesive power of the Norris engine. The framing was of wood covered with iron plates, and was placed outside the wheels. The driving wheels had two outside bearings. The cylinders, although outside of the smoke-box, were placed so as to give a connection to the crank, inside of the driving wheels. The crank was formed in the driving axle, but instead of being made as a complete double or full crank, the neck, to which the connecting rod was attached, was extended through and fastened into a hole in the driving wheel, the distance from the centre being equal to the throw of the crank. A simple straight pin fitted to the centre of the wheel, and extending outwards, formed an outside bearing for the axles. This device of Mr. Baldwin's was most ingenious and efficient. It simplified by more than one-half the making of the crank shaft, and increased its strength, and at the same time caused the thrust of the cylinder to act close to the driving wheel inside, in the same manner as the outside crank pin. With the introduction of the outside cylinder, this mode of making a crank axle has gone into disuse. The guide bar for the cross-head, which had a double V top and bottom, was clasped by the cross-head, and being hollow and with valve-chamber attached, was made to serve the purpose of a force pump. The valve-gear, already described, was placed under the foot-board, and although efficient, was cramped for room, the excentric rods consequently being rather too short.

In workmanship and proportion of parts the Baldwin engine was the superior of the two class of locomotives that had then become, in their manufacture, an important feature in the trade of Philadelphia.

M. W. Baldwin in 1834 and 1836 had much the advantage of the Norris establishment, as he had had from the first, in being a good practical machinist himself, and in having had some experience in steam engine building previous to the making of the "Ironsides," in 1832; whereas William Norris, after Col. Long retired, in 1833–34, having then no engineering or practical knowledge of engine building, was left dependent entirely upon hired skill, which at that time, in the construction of the locomotive, was most difficult if not almost impossible to find. Mr. Baldwin had also the great advantage of better workshops and better tools at the commencement of this new business than his early competitor; hence his success was at once more decided, and the improvements in his locomotives, both in design and in workmanship, much more important from the beginning. It is needless to speak to this audience of the "Baldwin Locomotive Works" of to-day. With a record of forty years, during the early years of which it passed successfully through many vicissitudes, it maintains its well-earned character of the first locomotive manufactory, both in quantity and quality, in this country; and it is doubtful whether it is not now the equal to, if not the superior, in these particulars, of any establishment doing similar work in the world.

The Baldwin engine of 1836, with its driving axle behind the fire-box, was steady at high speeds, but with insufficient adhesion to the rails.

The Norris engine, of the same date, having a great proportion of the weight overhanging the driving axle, although having adhesion equal to its cylinder power, was unsteady on the rails. Improvement rested between the two systems of Baldwin and of Norris.

In the spring of 1835 the firm of Garrett and Eastwick, then making steam engines and light machinery in Philadelphia, commenced the building of a locomotive engine for the Beaver Meadow Railroad. This firm, having no practical knowledge of this new machine, called to their assistance, as foreman, Mr. Joseph Harrison, Jr., a young man of twenty-five, and a good practical workman, who had been employed for nearly two years as a journeyman in the Norris works, and had been schooled, during that time, amidst the indifferent successes or real failures of Long and Norris, and Wm. Norris & Co. The first locomotive designed under the above auspices was called, when finished, the Samuel D. Ingham, after the President of the road.

It had outside cylinder connections, then not much in vogue,—running gear after the Baldwin type, with one pair of driving wheels behind the fire box, and with four wheel truck in front. It had the dome or "Bury" boiler. This engine had some points about it which differed from any locomotive that had preceded it. Its most distinguishing feature was an ingenious and entirely original mode of reversement, invented and patented by Mr. Andrew M. Eastwick, the junior member of the firm. It is scarcely possible to give a correct idea of this device without a model or drawings, but its principle consisted in the introduction of a movable block or slide, called a reversing valve, between the usual slide valve and the opening through the cylinder face. This reversing valve had an opening through it vertically for the exhaust, and two sets of steam openings, corresponding, when placed opposite thereto, to the openings on the cylinder face. One set, called direct openings, passed directly through the valve, and when set for going forward, made the usual channels to the cylinder. The second set of openings through the reversing valve, called indirect openings, and coming into play when the engine moved backwards, passed from the upper surface of the valve but half way through it, and thence were diverted laterally to the side of the valve, and thence along the side and again laterally, came out of the under side where the reversing valve rested against the valve face of the cylinder, directly opposite a second indirect opening on the upper surface of this valve. When the reversing valves were set for going forward, the direct openings were placed exactly over the steam openings on the cylinder, whilst the indirect openings came over the solid surface of the cylinder face, and were then entirely out of use. The exhaust opening through the reversing valve in this case, came directly opposite the exhaust opening on the cylinder. The slide valve, never detached from the excentric, moved over the direct openings in the usual way. Moving the reversing valve to the opposite end of the steam chest from where it had been placed in going forward, and the case was different. Then, steam entering the reversing valve at the upper side, instead of going directly into the cylinder as before, was diverted in the manner just described, and came out at the cylinder face at the opposite end from whence it had entered on the slide valve face, on the upper side of the reversing valve, and thus the direction of the engine was changed from forwards to backwards, or *vice versa*, without detaching or re-attaching any of the moving ports of the valve gear. The principle and action of Mr. Eastwick's invention may be

guessed at from what has been described, although its detail may not be so easily made out. This new arrangement, neat and efficient as it was, had its defects, which no doubt interfered with its general use. It increased by the thickness of the reversing block, the length of the steam openings, in going forward, and further increased their length in going backwards. It also prevented the use of a long lap on the slide valve, for, any lead of the excentric in going forward, causing a corresponding delay in receiving steam in moving backward. In reviewing these defects, the beauty and originality of Mr. Eastwicks' device must not be overlooked. Nothing for the same purpose, so novel in its mode of action had preceded, or has succeeded this invention of a Philadelphia mechanic, and it is doubtful whether any locomotive has since been made with so few moving parts as this first engine of Garrett & Eastwick. This engine had for the first time, the rear platform covered with a roof to protect the engineman and fireman from the weather.

The success of the "Samuel D. Ingham" was quite equal to any locomotive of its class that had been built up to that period in Philadelphia, and orders came to the makers from several sources for others of the same kind.

In 1836, Henry R. Campbell, of Philadelphia, "in order to distribute the weight of the engine upon the rails more completely, patented the duplication of the driving wheels, placing one pair behind and one pair in front of the fire-box, using the swivelling truck in front, of Baldwin's and others. Mr. Campbell subsequently made an engine after his patent, which was tried on the Philadelphia and Germantown Railroad, and although not a decided success, it was a great step in the direction in which improvement was most needed. Its principal defect consisted in its having no good means of equalizing the weight on the driving wheels so as to meet the undulations in the track. To remedy the defects in the Baldwin, Campbell and Norris engines, Garrett & Eastwick (soon thereafter changing their firm to Garrett, Eastwick & Co., Joseph Harrison, Jr., becoming the junior partner) commenced in the winter of 1836–7 a new style of locomotive, for the Beaver Meadow Railroad Company. Adopting the Campbell plan of running geer, they aimed towards making a much heavier engine for freight purposes than had yet been used. This could be only rendered possible on the slight roads of the country, at that time, by a better distribution of the weight upon the rails. In the first of the improved engines made by Garrett

& Eastwick for the Beaver Meadow Railroad, Mr. Andrew M. Eastwick introduced an important improvement in the Campbell eight wheel engine, for which he obtained a patent in 1836. This improvement consisted in the introduction under the rear end of the main frame of a separate frame, in which the two axles were placed, one pair before and one pair behind the fire box. This separate frame was made rigid in the "Hercules," the first engine in which it was used, and vibrated upon its centre vertically, and being held together firmly at the ends, both sides at all times moved in the same plane, thus only accommodating the undulations in the track in a perfect manner when the irregularities were on both rails alike. The weight of the engine rested upon the centre of the sides of this separate frame through the intervention of a strong spring above the main frame, the separate frame being held in place by a centre pedestal bolted to the main frame, the centres of the frame vibrating upon a journal sliding vertically in this centre pedestal. Mr. Eastwick's design was, however, somewhat imperfect, in not accommodating the weight of the four driving-wheels to the irregular undulations no both tracks. There were other minor improvements in the "Hercules," one of which was the introduction for the first time into steam machinery of the bolted stub-end instead of the old-fashioned and unsafe mode of gib and key for holding on the strap. This device, an idea of Mr. Harrison's, is now universally used in the connecting rods of the locomotive engine. The "Hercules," when put at work on the Beaver Meadow Railroad, proved a great success, and led to other orders for the same class of engine. This division of the weight on more points of the road, and its more perfect equalization thereon, seemed at the time, as it has proved since, to have been the commencement of a new era in the history of the locomotive. To remedy the defect, as before mentioned, in these first eight-wheel engines incident to Mr. Eastwick's plan, an improvement was patented, in 1838, by the junior partner of the firm of Eastwick & Harrison. Mr. Harrison's patent showed many ways of carrying out the principle of his improvement, but the one preferred consisted in placing the two driving axle bearings in pedestals bolted to the main frame in the usual manner, and by the use of a compensating lever above the main frame, vibrating on its centre, at the point of attachment to the main frame, the ends of the lever resting on the axle-boxes by means of pins passing through the frame. These levers vibrated on each side of the engine separately, and thus met all the uneven-

ness in both rails within a certain prescribed limit, which was governed by the play of the axle-boxes in the pedestals. This arrangement of Mr. Harrison was simpler, lighter and cheaper than the one that had preceded it, and was used in all the eight-wheel engines built by Eastwick & Harrison after the second one. In all engines now built in this country or in Europe with more than six wheels this device of Mr. Harrison is used in one or other of the different ways indicated in his patent.

In the summer of 1839, Eastwick & Harrison received an order from the Philadelphia and Reading Railroad Co., through the Chief Engineer, Mr. Moncure Robinson, for a freight engine that had peculiar points. This engine was designed generally upon the "Hercules" plan, but it was stipulated in the contract that the whole weight should be *eleven tons* gross, with *nine tons* on the four driving-wheels. It was also stipulated that it should burn anthracite coal in a horizontal tubular boiler. To distribute the nine tons on the driving-wheels, the rear axle was placed *under* the fire-box, and somewhat in advance of its central line, instead of being behind the fire-box, as in the "Hercules." This arrangement of the rear axle permitted nine tons of the whole weight of the engine to rest on the four driving-wheels. The boiler was of the Bury type, and the fire-box had the then unprecedented length, outside, of five feet. The tubes, two inches in diameter, and only five feet long, were more numerous than usual, and filled almost to the top, the cylinder part of the boiler. Cylinders 12½ inches in diameter, 18-inch stroke, using no cut-off; driving-wheels 42 inches. The Gurney draft-box was used with many small exhaust-jets, instead of one or two large ones. It is believed that this engine used for the first time the steam jet for exciting the fire when standing. The engine here described, called, when finished, the Gowan and Marx, after a London banking firm, excited much attention in the railroad world by its great tractive power, compared with its whole weight. On one of its trips (February 20th, 1840) it drew a train of *one hundred and one* four-wheel loaded cars from Reading to Philadelphia, at an average speed of 9·82+ miles per hour, nine miles of the road being a continuous level. The gross load on this occasion was 423 tons, not including the engine and tender, which, if the weight of the tender is counted, equalled *forty times* the weight of the engine. See "Journal of the Franklin Institute," 1840, vol. 25, page 99, Report of G. N. Nicols, Supt. Philadelphia and Reading Railroad, which closes as follows: "The above performance of an eleven-ton engine

is believed to excel any on record in this or any other country." It may be doubted whether it has ever been excelled since. How strangely this feat of the Gowan and Marx compares with the trials on the Liverpool and Manchester Railroad in October, 1829, when all that was required of the competing locomotives was, that they should draw about *three times* their own weight, tender included, on a level track, five miles long, specially prepared for the trial.

In 1840 the Gowan and Marx attracted the particular attention of the Russian engineers, Colonels Melnikoff and Krafft, who had been commissioned by the Emperor Nicholas to examine into and report upon the various systems of railroads and railroad machinery, then in operation in this country and in Europe. The result of their examination was favorable to the American system, and when the engineers above named, made their report on the construction of a railroad from St. Petersburg to Moscow, an engine upon the plan of the Gowan and Marx was recommended as best adapted to the purposes of this first great line of railroad in the Empire of Russia, and Eastwick and Harrison were requested to visit St. Petersburg with the view of making a contract for building the locomotives and other machinery for the road. Mr. Harrison went to St. Petersburg in the spring of 1843, and in connection with Mr. Thomas Winans, of Baltimore, a contract was concluded with the government of Russia, at the close of the same year, for building 162 locomotives, and iron trucks for 2,500 freight cars. Eastwick and Harrison closed their establishment in Philadelphia in 1844, removing a portion of their tools and instruments to St. Petersburg, and there, under the firm of Harrison, Winans and Eastwick, completed, at the Alexandroffsky Head Mechanical Works, the work for which they had contracted, much additional work during the progress of the contract, being added thereto. The first contract was closed in 1851, at which time a second contract, by two members of the firm, for the repairs to the rolling stock of the St. Petersburg and Moscow Railroad, was entered into, which continued until 1862.

The eight wheel locomotive of Eastwick and Harrison, made its first reputation as a freight engine only. In 1842, two of these engines were built by E. and H. for the Baltimore and Ohio Railroad, which were specially designed for running passenger trains at extra fast speed. One of these engines, during the year 1844, ran the large aggregate of 37,000 miles, which, by the annual report of the Baltimore and Ohio road for that year, is assumed to be the largest

result on record up to that time. The locomotive of the Hercules type, and those that immediately followed it from the same makers, is now the standard engine for passenger trains in this country, and is being introduced in Europe for the same purpose, but it is not now used generally as a freight engine.

In the years following the early efforts of Baldwin, Norris, Campbell and Eastwick and Harrison, other Philadelphia engineers and machinists entered the field in the manufacture and improvement of the locomotive. Mr. Henry R. Campbell built several very creditable six-wheel engines. James Brooks & Co., aided by Mr. Samuel Wright, a young man of good practical skill, constructed a locomotive which had several new points worthy of notice. Its running gear was after the type of the six-wheel engine of Baldwin, with one pair of driving wheels behind the fire-box, and with outside cylinder connections. The cross-head slides were made in the form of a cylinder, bored out and arranged to serve the purpose of feed-pumps, the cross-head forming the piston of the pump. The connecting rod entered the lower or open end of the slide, which was large enough to allow clearance at the angles of the rod. The usual valve chamber was placed at the upper end of the slide and thence a pipe led to the boiler. This mode of arranging a feed pump was more ingenious in design than useful in practice, and was not repeated in a second engine built by the same makers. A second point in the Wright engine was the mode of reversement, which was the same in principle as the Costell plan. The slide valve was open through the top, from the exhaust cavity underneath, and terminated in a cylindric form in which was fitted a metallic spring-piston closing up the opening through the valve. When the engine was going forward, steam from the boiler entered the steam chest, and the slide valve acted in the usual manner. When going backward, by the peculiar arrangement of a slide valve which acted also as a steam or throttle valve, the steam from the boiler, by a process similar to a two-way cock, was turned under the cylinder slide valve and into the cavity of the exhaust, forcing the piston in the top of the valve, upward and against the evenly planed under surface of the steam chest lid, the exhaust pipe becoming the steam chest, and the steam chest the exhaust pipe, and *vice versa* when the movement of the engine had to be changed.

This mode of throttle valve and reversement valve in one, combined with the piston slide valve, was a most simple and certain arrangement. It had, with Costell's, the same defect in the matter of the lead

of the slide valve as the Eastwick mode of reversement. Eastwick and Harrison made two locomotives in 1838, with vibrating valves moving on faces on the side of fixed cylinders, reversing Costell's plan. In these two engines the throttle valve and reverse were combined in the same manner as in the Wright and in the Costell engine, by the movement of a slide valve moving over three openings.

With the second engine of James Brooks & Co., also designed by Samuel Wright, an attempt was made to secure the adhesion of the forward swivelling truck wheels in combination with one pair of driving wheels behind the fire-box, which worked with fair practical success. This same idea was carried out by Mr. Baldwin at, or near this period. James Brooks & Co. did not continue the building of locomotives after this second trial. About this time, Messrs Charles & Escoll Sellers, of the firm of Coleman Sellers & Sons, of Philadelphia, built a locomotive somewhat after the plan of the Baldwin engine. It is not remembered that this engine had any specially original points except in the arrangement of the draw-link between the engine and tender, whereby the point of attachment to the engine could be raised or lowered, so as to bring more or less of the weight of the tender for increasing the adhesion of the driving wheels. Mr. Escoll Sellers, some years later than this, invented and patented the plan of central rail, with vertical friction rollers, the same as has been used up to a recent period on the "Fell" railroad crossing Mont Cenis, before the completion of the tunnel. Edward Young, at Newcastle, Delaware, and Leonard Phleger, Philadelphians, also made improvements in the locomotive.

In 1846 Septimus Norris, a brother of Wm. Norris, patented a ten wheel locomotive with six driving wheels, combined with swivelling truck forward. Several of these engines were built for the Philadelphia and Reading Railroad. It is true that from amongst all these pioneers in the manufacture and improvement of the locomotive engine, the Baldwin Locomotive Works only remains in Philadelphia at this time. But the fact that the smaller establishments exist no longer, should not cause the workers in the early day to be forgotten. They helped to attract the attention of the railway world towards Philadelphia as the great source of supply for railroad machinery, and in this they helped also to make it possible for us to have to day, the great locomotive establishment, which is now the pride and boast of Philadelphia.

The story has now been told of what Philadelphia engineers and

mechanics have done at home, in the early and later day, in the development and improvement of the locomotive engine. This record would not be complete without some reference is made to that which they have done outside of Philadelphia. These workers can be found everywhere, and for nearly forty years Philadelphia skill has been sought for to fill responsible places in all parts of the United States, in the West Indies, in South America and in Europe, and even in British India.

In tracing this history from the date of Colonel Long's first effort to the period at which the locomotive has reached its present perfection, it cannot but be noted how persistently and tenaciously Philadelphia mechanics and engineers clung to the early idea of making an engine that should have important original traits, and it is further remarkable that in no single instance has there been even a desire to merely repeat what had been done elsewhere. The eight-wheel engine of Campbell,—first conceived by him in 1836, and with the added improvements of Eastwick and Harrison in 1836 and 1837, subsequently copied by Baldwin, Norris and all other makers, is to-day, after more than thirty years of trial, with but little change except in its greatly increased weight,—the passenger locomotive of this country. Baldwin, Norris and others did much toward the improvement of the freight engine, and have earned a well-merited reputation in its construction, which the present proprietors of the Baldwin Locomotive Works most manfully maintain. Take the best locomotives now made in the United States, and it will be difficult to find one that has not upon it some distinct impress of a Philadelphia mechanic, and it may be fairly claimed that they have made a mark upon this most important and useful machine that is eminently Philadelphian.

In the long future, when the story of the locomotive is inquired into and rehearsed by the curious, as it will be, Philadelphia's honors fairly earned, will not be overlooked, nor should the names of those who have aided in earning this honor be forgotten.

It is not only in the improvement of the locomotive that Philadelphia engineers and mechanics excel, but they are widely known and appreciated as the designers and manufacturers of all other kinds of railroad machinery. They are particularly noted for perfection in machines and instruments used in building the locomotive engine.

The ordinary observer, in looking at the perfect locomotive of the present day, and the perfect means in material and in instruments,

which render it now so easy to make it what it is, bestows little thought upon the amount of labor, both of brain and body, that has been expended in bringing it to this perfection. It is plain from the record, that there was no Royal road to the end attained.

The story of the railroad has been in part told in this history, and it is shown in how little estimation it was held up to near the close of the decade ending with 1830. Its present value is patent to every one, and it looms up as something so vast as almost to disarm discussion. But this value remained almost entirely latent from the time the first iron rail was laid down until the improvements in the locomotive in 1829. From that time the railroad took the place it fills to-day, a result only made possible by the little machine that we now see glinting in the sunlight as it crosses field and meadow with its lengthened train,—that we hear in the darkness of midnight, and that even now is threading its way in Cimmerian gloom through the Alpine tunnel, with a mile of rock above its head, making it possible to change the dreary cold of winter to the summer glow of an Italian sky in less than one short hour. It was this little machine which never tires in its work, and which we never tire in the looking at; that evoked the latent spark, toward which the student turns from his books, the ploughman stays his team, and the mechanic, the mother and the playful child, stop in their pursuits, to gaze and wonder as it passes by,—not once nor twice, but ever, as it speeds along, they stop and wonder as at something new and never seen before.

It is this wondrous steed,

"With iron nerves, and lungs of fire."

that has made the railroad what it is, that has won this triumph over Time and Space.

Philadelphia, December, 1871.

An Experimental Gas Works.—The German Society of Gas and Water Experts have under consideration a plan for establishing an experimental gas works, for the purpose of deciding various questions which may arise in the details of their profession, by actual experiment. The proposed plan, if adopted, will be upon a large scale, so as to reproduce, as far as possible, all the conditions met with in practice.

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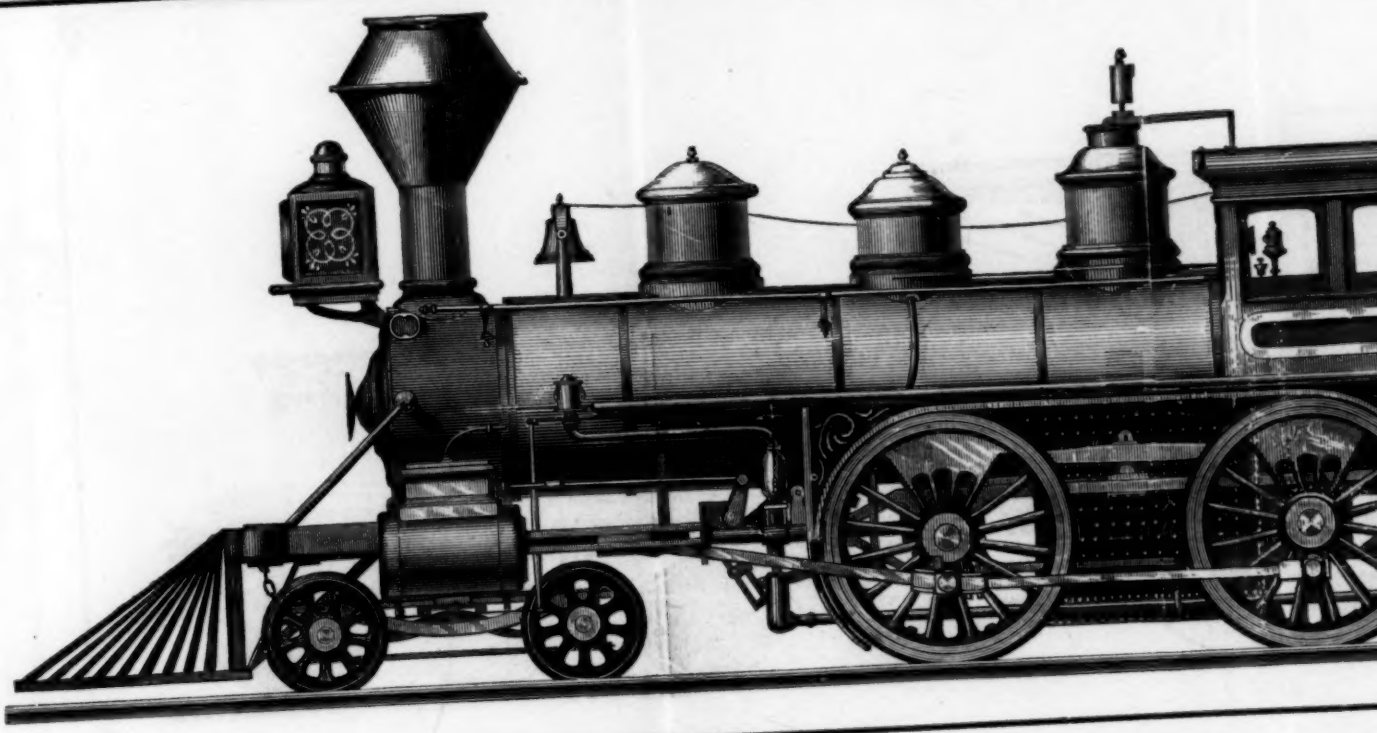


PASSENGER E

BALDWIN LOCOMOTIVE WORK

BUILT BY M. BAIRD & CO.,

ENGINE.

WORKS, PHILADELPHIA.

D & CO., 1872.

practice.

KEOKUK AND HAMILTON BRIDGE.

By Joseph S. Smith, Resident Engineer.

(Continued from page 195.)

Construction of the Work, Delays, &c.—A change in the first arrangement of the spans having been decided on, in order to leave a clear water-way of 160 feet on the square for the draw span channels, final plans were prepared early in June, 1869. In order not to be delayed for stone during the extreme low water season, when navigation on the rapids becomes very uncertain on account of the many shoals, large quantities of the stone were brought down and piled on the levee for use in the construction of the levee abutments and walls of the approach. In fact everything promised busy times for all connected with the work, but the unusually high water season extending over the months of April, May and July, part of August, all of September and October, and a part of November, seriously retarded operations, so that work in the river had to be postponed to the following season. In the meanwhile the available time was turned to account; grading was commenced on the eastern approach in March, but the spring rise early in April flooding the borrowing pits, compelled the contractors to suspend operations; and it was not till late in November that any amount of work was done on it, although twice attempted, once in June and again in August, during low stages of water. Grading on the western approach was begun during May, but only completed during October, operations being suspended during June, August and September. The western levee abutment, with its foundation carried down 17 feet to the rock, through the old *débris* of sticks of oak, rip-rap, scrapings of steamboat furnaces and other material deposited during the early days of Keokuk, was completed early in June during a low stage of water, and on the 15th the contractor commenced placing the coffer-dam for the eastern abutment of the main bridge. Although pumping out was commenced early in July, it was the 6th of August before the excavation for the foundations could be got at. The first stone was laid August 12th. On the 19th the high water flooded everything; the dam having been raised above the flood, work was resumed on the 21st, and two courses laid on the south wing by the 23d, when operations were again suspended by the "Father of Waters," who seemed determined during the entire time of construction to prevent it in one way or another. Nothing was done on this dam until the 6th of November, from which

time until the 9th of December the masonry was pushed ahead, but not finally completed until March of the following season. The coffer-dam necessary for the western approach masonry and western rest pier was begun in December, 1869; it was 260 feet long, by an average width of 105 feet. It was pumped out 23d of January, 1870. Masonry commenced on 8th of February. Being favored with a splendid building season during the usually rigorous months of February and March, the masonry was raised above the water level of the river on the 8th of March, and the dam allowed to fill to save labor in hoisting material. We were not yet out of the reach of the water, for the spring flood, beginning on the 19th of March, after a lively race between the masons and the rising water, flooded the greater portion of the work by the 30th of March. Being well advanced by the middle of May, and the river once more at a favorable stage, it was determined to push the construction of the piers. Accordingly, the coffer-dam for the first pier from the eastern shore was placed in 12½ feet of water on the 20th of May—a few days over eleven months since the adjoining abutment had been commenced.

The system devised for securing an anchorage on a rock bottom with but few fissures, and no certainty of holding an anchor long enough to build cribs in place as a protection against rafts, and obtain slack water for the construction of the dams, although not original, may not be uninteresting, and was as follows: A small scow or lighter was first anchored at the pier site, its position being determined by triangulation; the diver's scow, with pumping apparatus, &c., was securely anchored (often with a great deal of labor and loss of time from dragging of anchors) about 60 feet above the first lighter and in the line of the pier axis; a hole was then jumped into the bed rock of the river from this scow, with a long drill passing through a large-sized gas pipe, the diver directing operations at the bed of the river, and preventing the hole filling with the shifting sands. Into this hole was then securely fastened a bolt with a clevis and chain attached, and the placed marked with a buoy. Having now something to fasten to, it was an easy matter to construct cribs and fill them with stone, and in the slack water below to put together coffer-dam frames. Five of these anchor bolts were required, on an average, to each pier. When the frame of the dam was all ready it was set in place by triangulation, with one instrument on the bridge line, then sunk to place, sheeted, and filled above the water level. When pumped out and ready for the masonry, the distance was accurately

measured with a steel wire under strain, measured on a spring balance sufficient to swing it clear of the river, the span length being tested from previous established distances, and the pier axis turned off with an instrument, thus insuring the parallelism of the piers at the required distances.

The protecting cribs were built in two parallel courses, 10 feet apart between out and inside timbers, of 12 x 12 pine timber, half notched into each other at the up-stream point and shoulders, with cross ties also notched into the side timbers, leaving spaces between of six inches, and the whole well bolted together with long bolts reach-through all the timbers. The form of the up-stream end was a right angle; the sides below the shoulders were not parallel with the axis of the pier, but were somewhat flared to receive and protect the coffer-dam and afford protection to barges or floating derricks during the construction of a pier. When sufficient timbers were placed to reach the bed of the river, a course of heavy plank was laid at the water level, and the whole crib well weighted down with stone. So soon as the masonry was well above water these cribs were easily removed to another pier site.

The form of the coffer-dams corresponded to that of the piers, except that the down-stream end was straight. The clear space across the dam between side timbers was 20 feet, leaving 5 feet in the clear of the masonry at foundation courses. The outside and inside timbers of the sides were of 12 x 12 pine, in three courses, vertically three feet apart, securely bolted to vertical posts placed 8 feet apart on the outside of the side timbers, and resting on the bed rock when the frame was loaded down in correct position. The sheet piling was of 2″ pine plank, spiked on to the horizontal timbers after being driven well down on to the rock to broom up the ends. A clear space of seven feet was thus left, which was well puddled. Long bolts, 1¼ in. diam., with nut and washer on each end, reaching through the side and vertical timbers, tied the frame well together. This form of dam answered very well in from 8 to 16 feet of water.

The first stone was laid in the first pier from the eastern shore June 15th, and the last in the coping of rest pier was laid Dec. 3d, 1870. During these five and a half months eleven piers were built, containing 4282 cubic yards of masonry, or one every two weeks—a daily average of 30 cubic yards, including time occupied in preparing dams, cribs, &c., for foundations. The summer season was an unusually hot one, the thermometer for forty days averaging 100° in the

shade at mid-day, and was very trying on all. Although the work was done during the favorable building periods of two seasons, yet with an ordinary season it could have been completed in the required time.

Spans.—The general arrangement of the spans is as follows: Commencing from the Iowa shore, where the main channel of the river is, the dimensions of that part of the bridge are fixed by the Act of Congress, and call for two fixed spans of 250 feet for the passage of rafts, and of a pivot draw having two openings of 160 feet in the clear. The remainder of the bridge was divided into eight fixed spans, that being the most economical arrangement determined by the ratio of cost between span and pier. The final arrangement of the spans was as follows: The draw span is, from centre to centre of rest piers, 378′ 9¼″, leaving a clear water-way on both sides of the pivot pier of 160 feet, measured on the square with the pivot pier protections, and is the longest draw-span yet erected on the Mississippi River. The adjoining fixed spans are one of 257′ 1⅛″, one of 256′ 6″, leaving a clear water-way of 250 feet for the passage of rafts; then follow three spans of 162′ 9″ each, one of, 151′ 4″, then three of 164′ 7″ each, and one to the centre of east abutment, of 163′ 7″—all measured from centre to centre of piers, making the total length of superstructure 2188′ 9⅛″, and from back wall of western rest pier to back wall of east abutment 2192 feet.

Superstructure.—The superstructure was contracted for by the Keystone Bridge Company, of Pittsburg, Pa., and is the well-known Linville & Piper wrought iron bridge, a quadrangular girder with double intersections. The designs for the superstructure were furnished by J. H. Linville, C. E., the drawings being carefully worked up under the direction of Mr. M. Benner, at Pittsburg. It is a through bridge, on a skew of 17¼°, with a distance of 21′ 6″ from centre to centre of trusses, having a single line of railway track and two tramways for local traffic, the track being placed in the centre between the tramways. On each side of the bridge, outside of the trusses, are footwalks, 5 feet wide, protected by light and substantial iron lattice railings, and are supported by the floor beams, which are extended beyond the trusses for this purpose. The floor is planked throughout with oak. The depth of truss for the short spans is 21 feet from the centre of the lower chord to the top of the upper one, and for the longer spans is twenty-seven feet. The under side of the chord is placed 10 feet above the level of high-water mark of 1851, the high-

est water known at this point. The lower chord of the fixed spans is formed of wrought iron bars, with pin connections. The bars are made by upsetting the ends of flat bars of rolled iron till an increase of section is obtained, then the hole for the pin is drilled, thus avoiding the possibility of defective welds. The upper chord is formed of two channel beams outside, with two I beams between them, 9 inches deep, placed side by side and united by a plate rivetted to their upper flanges. The width of chord is 22 inches for the short spans, and two feet for the long ones. The posts are of wrought iron, of the Linville pattern; the sections are rivetted close together, at top and bottom, but separated at the centre, with ferrules on the rivets, thus offering facility for painting both out and inside. The intermediate posts rest on cast iron pedestals, with a gib block between the pedestal and floor beams; the end posts rest on cast iron pedestals, and these on cast iron wall plates, extending across the pier; at one end of each span a set of rollers is placed between the pedestal and wall plates, to provide for the expansion of the material. The ties are of square iron, with a welded loop at the lower end, passing around the pin. The upper end is provided with a nut, resting on cast iron angle blocks. The ties have also upset ends, and the section is not reduced by having the thread cut on it. The floor beams are suspended with four rods of four square inches area each, two under each post, passing through a heavy cast iron washer, and secured with nuts. The floor beams are formed of two 10-inch channel beams, well trussed with two rolled plates of iron, $4\frac{1}{2}''$ x $1\frac{3}{8}''$ each, and are 35′·5″ long. The draw span is similar to those erected by this Company at Dubuque and Kansas City, having an arched upper chord. Its length over all is 378′·3″, its extreme length over both long sides is 384′·11″. The difference in skew for this span as well as for the fixed spans is 6′·6¾″. The depth of truss at end posts is twenty-seven feet, corresponding with the fixed spans, and at the centre is thirty-five feet, giving a versed sine of 8 feet. The posts are of the same pattern as on fixed spans. The top and bottom chords are made of channel and I beams, 9″ deep, with a top plate rivetted to their upper flanges and cross bracing pieces on the under side of chord; the chords are made continuous, being securely rivetted together with side plates. The ties are round in section, with both ends upset for screws. The four centre angle blocks are forged, the remainder are of cast iron. The turn-table has an external drum, 30 feet in diameter, made of wrought iron rolled plates, well rivetted together. Under the drum are the

poney wheels, resting on cast iron track segments, and serving to keep the truss steady when opening. There are two levers for turning the draw by hand, but, for greater ease in turning so large a mass and having more perfect control of it, a steam engine is provided, placed under the roadway and attached to the drum. The centre part around the cone weighs nine tons and is of cast iron; it is suspended on one of Sellers & Co.'s, Philadelphia, patent pivots by 12 three-inch adjusting screws. A latch, secured to the end floor beams of the truss, holds the draw in place; these latches, together with the wedges under end posts, are worked from the centre with levers. Eight hydraulic rams, each 4 inches in diameter, placed within the end floor beams, and having pipes connecting them with the engine at the turn-table, and driven by steam, are used to raise the trusses when swung into position well above the wall plates on the rest piers, and to enable the wedges to be thrust well under the end posts, so as to prevent any distortion of the truss when one arm only is loaded, and to relieve all strain at centre on upper chord. They raise end of draw about $\frac{3}{4}$ of an inch, and have given very satisfactory results, working steadily and surely. The spring of the safety valve is rated to lift at 2500 lbs. pressure per square inch.

Erection of Superstructure.—The first pier having been completed on the 5th of July, 1870, the falseworks for this span were put in during the month, and it was swung off its bearings on the 6th of August. Although the four adjoining piers were raised well in advance of the superstructure, yet it was not allowed to be raised until a temporary trestle approach had been built for the Ferry Company, so that they could land their boats below the bridge. This caused a delay of about two weeks of very valuable time, during a low stage of water. Matters having been thus satisfactorily arranged, the superstructure was proceeded with, and the remaining seven short spans were raised before the ice formed. As the work had now reached that portion of the river where falseworks would be exposed to danger from passing rafts and steamboats, it was decided to put in cribs filled with stone and place a strong boom above, but resting against them, to fend off the rafts, and during the running ice to protect the falseworks in a measure from its shock. Whilst raising the long span, in the middle of December, the weather became intensely cold, the thermometer remaining at or near zero for several days, and the heavily running ice threatened to carry everything before it; but the patient endurance of the cold and wind by the men overcame all ob-

stacles, and the span was got out of danger in good time. The river gorged on Christmas Day, and as soon as the ice became safe the removal of this falsework to the remaining long span was commenced. This was a very tedious operation, as they had to be taken apart and the legs cut loose from the ice, and when put together again fresh holes had to be cut through the ice to get them into place. Seven of these bents had been raised in the last span when the January thaw rendered the ice very unsafe for crossing heavily loaded teams. The ferry-boat forced a channel, below the bridge, to the Illinois landing, on the 10th of January. The heavy pressure of the gorges that had recently formed on the rapids closed this channel the same evening, taking out all the bents, booms and cribs; the following afternoon the pressure became so great that a channel was forced through along the west shore, and all the ice from above moved out, at the same time throwing down seven bents of the lower falsework raised for the draw span. Although the damage was great, and lumber of proper lengths not to be procured nearer than Chicago, yet, having an open river, it was determined to push the work; but, inside of 24 hours, on the 12th of January, the thermometer fell 64°, and on the 14th and 15th, after a very severe storm of hail, sleet and snow, the river gorged again, and crossing on foot was resumed by the 19th. The uncertain state of the weather during the remainder of January and February rendered the ice very uncertain for raising the falseworks for the last span; but, as the draw span was protected with an ice-breaker pier rest, the work was resumed with an increased force and pushed vigorously, although under serious disadvantages. After a warm period, the ice finally took its departure in a very quiet manner early on the 25th of February, having been closed nearly two months. This break up was general all the way up the river, and was followed by a high stage of water, together with a large amount of heavily running ice, lasting to the 2d of March. The falseworks for the last span were commenced, in 25 feet of water, on the 6th of March. As the greater length of the trestles was under water, and the velocity of the current equal to about six miles per hour, it became a difficult matter to place these trestles and to hold them in place. By loading the bottom of the trestle legs with railroad iron the difficulty was finally overcome. The iron work was commenced at noon of the 20th and the span swung off its bearings at noon of the 24th, just five hours before the whole of this falsework was carried away by a raft that was totally wrecked by striking on one of the piers in such a manner as to

be thrown against the falsework. Although the shock to the span was very great, yet no damage to the iron work could be perceived, but it afforded one more convincing proof of the advantage of a wrought iron upper chord over a cast iron one, for the latter would have most certainly failed under the great cross strain that was brought upon it by the forcing out of the falsework.

The draw span was swung for the first time during the afternoon of the 29th of March, and everything found to come together in the most satisfactory manner.

The first locomotive crossed the bridge from the west side on the 11th of April, although one had been out from the eastern end on the 1st of April as far as the first long span, and the bridge was ready for railway traffic on the 15th of April.

A formal test of the bridge was made on the 18th of May, by Mr. Henry Petit, C. E., acting as Inspecting Engineer for Mr. J. Edgar Thompson, President of the Pennsylvania Railroad Company. For the results of these tests the reader is referred to this Journal, Vol. LXII, page 47, (July, 1871,) where they are given in detail.

Quantities Contained in the Substructure.

47,000 cubic yards of embankment in approaches.
4,500 " dry slope wall "
4,700 square yards of McAdamizing "
9,096 cubic yards of masonry in piers, abutments, and viaduct approach.
60 tons of iron in piers, pier rests and protection to pivot pier.
700 M ft. oak and pine lumber in permanent works.
300 M ft. pine lumber in temporary works.
2,900 cubic yards of crib-filling.

Quantities Contained in the Superstructure.

1174 tons wrought iron in fixed spans.
348 " cast " "
410 " in draw span.

1932 tons.

290,000 ft. oak lumber in flooring, } Permanent works.
153,250 ft. pine " in stringers, }
125,000 ft. " " in falseworks in erection of spans.

Total time in laying masonry, 350 days.

Total time of constructing masonry, 18 months.
Average cost of masonry, per cubic yard, was $16.
" " ten piers, complete, was $8,400.
" time of constructing a pier was 15 days.
Total contract price, $800,000.

ON THE FLOW OF WATER IN RIVERS AND CANALS.

By J. Farrand Henry, Ph. B.

(Continued from page 113.)

Such being the state of the science, it is not strange that the new theories of the flow of water in rivers, and the new formulæ deduced by Humphreys and Abbot were at once accepted by the scientific world. Dr. Hagen, of Berlin, the oldest and ablest of German hydrauliciens, after speaking of the many commendatory notices of the Report on the Mississippi, says:* "Thus the new formulæ were so praised, that the former unshaken belief in Eytelwin's formula suddenly vanished, and those of Humphreys and Abbot seemed about to take its place. I was therefore even then induced to warn my coworkers against such an unconditional acceptation of them, by showing their very weak foundation." Again, after describing his own very simple formula, given above (which he compared with the Mississippi observations and found the error only one-half as great as with their own very complicated one), he says (page 20): "If they only wished to obtain an analytical formula which would best agree with their observations, there was no need of taking into account the assumed resistance of the air, nor the other members which they have introduced." Humphreys and Abbot give a table of their own, and other observations computed by the different formulæ.

The difference between the observed and the computed velocity is in some cases as much as three feet per second.

On the other hand, these very formulæ, when used for the calculation of the discharge of water through pipes, give results which agree very well with the observations.

Dr. Brewster, in his Encyclopedia, gives an example of a pipe, 4 inches in diameter and about three miles long, with a fall of 51 feet, of which the average discharge for five years had been obtained. He computed the discharge by several formulæ, and gives the results as follows:

* Bewegung des Wassers in Strömen, von G. Hagen. Berlin, 1865. Page 5.

	C. F.
Measured discharge, 5 years' average. . . .	11·333 per m.
Calculated by Eytelwin's formula. . . .	11·355 "
" Girard's "	11·265 "
" Dubuat's " . . .	11·257 "
" Prony's "	11·502 "
" Young's " . . .	11.459 "

The agreement between the observed and calculated discharge is very close, and the simpler formulæ are rather better than the more complicated. The hydraulic mean depth of a river can be measured with nearly as great accuracy as the diameter of a pipe, and therefore the error which is found when we attempt to apply these formulæ to rivers must arise from inaccuracy in the measurement of the inclination. In a pipe, the fall can be obtained with great accuracy, and probably in a canal, where the cross section is uniform, the measured would not differ much from the true slope; but in a river, where the depth and width are constantly varying, and the fastest current is changing from side to side, the water cannot be a plane or a simple curved surface, but must form a warped surface, inclining towards one side or the other; for the fall, measured on opposite sides of a given reach of river, is rarely the same. Generally in swift rivers there is a back flow near the banks. Mr. Ellet states, in regard to the slope of the Mississippi, that "*it not unfrequently happens that while the mass of the water which its channel bears is sweeping to the *south* at at a speed of four or five miles an hour, the water next the shore is running to the *north* at a speed of one or two miles an hour. It is no unusual thing to find a swift current and a corresponding fall on one shore, towards the south, and on the opposite shore a visible current and an appreciable slope towards the north."

The surface level is also constantly changing, often sufficient to entirely mask the fall in a short distance.

In a length of a thousand feet, near the mouth of the Niagara River, where the current and inclination were ordinarily down stream, this change in the water level did not take place simultaneously at the ends of the selected line, and thus made the apparent inclination as often up stream as down.

The fall, therefore, must be measured for long distances not less than one or two miles, and great care must also be taken to have the water-level stations so situated that the velocity of the current near them is the same, for the water rises with an increase of velocity. M.

* Report, page 27.

Baumgarten found that in the swiftest current in the Garonne the water was over 0·4 foot higher than near the banks.

But in this long distance there may be bends, which by increasing the friction will decrease the velocity, and there will certainly be changes in the cross section and distance of the maximum velocity from the banks. These and other causes render the accurate determination of the inclination a very delicate matter, and in some cases an impossibility.

Dr. Hagen, in speaking of the observations of Brunnings, upon which Eytelwin based his formula, says:* "These observations are divided into certain groups, and a single inclination given for each group.

"It is noticeable that this agrees for one, and generally the first observation in each group, with that computed by Eytelwin's formula. This coincidence is so striking that we can hardly consider it accidental. * * * In fact, the falls were not measured, but computed by Dubuat's formula, and then compared with the velocity observations. Naturally, they should agree; indeed, they only disagreed because Funk computed the inclinations for each group, and not for each observation. That Eytelwin did not refer directly to Wiebeking's notes, but used Funk's computations, is proved by the fact that he copied a typographical error in Funk's work." And, after collating all the known observations when the velocity and slope were both obtained, he says of the few observations selected by Humphreys and Abbot, for comparison with their formula:† "Of these observations of Dubuat they only used two which best agree with their theory. These are the last-mentioned, and of one of these Dubuat says that, on account of the opening of the sluice, the velocity was too great. The other eight observations, which would certainly give a very different result, they rejected altogether. Besides these, nine other observations are noted in the American work, made in the Netherlands, Italy and Russia, of which detailed notes are missing."

In a supplement to the Mississippi Report, written by Gen. Abbot for the "Essayons Club" of Engineer Officers, the observations of MM. Darcy and Bazin are examined, the new formula applied to them, and the Mississippi observations computed by their formula. The arithmetical sum of the differences between the observed velocities and those computed by both formulæ are as follows:

* Bewegung des Wassers, page 4.

† Bewegung des Wassers, page 24.

TABLE XIV.

OBSERVATIONS.	SUMS OF DIFFERENCES.	
	H. and A. Formula.	D. and B. Formula.
Darcy and Bazin canals	14·085	7·158
Bayous and selected European observations	3·792	8·653
Mississippi River	2·584	13·284

Thus the error of the new formula applied to Darcy and Bazin's observations is double that of their own formula, while in the Mississippi the sum of the differences of the observed and computed velocities is nearly six times as much by the latter as by the former.

In Table XV the observed and computed velocities of the Mississippi are given, that we may examine them in detail.

TABLE XV.

Tabular Numbers.	Cross Section.		Inclination	Mean Velocity.			Discrepancy.	
	Area in sq. feet.	Mean Radius		Observed	D. and B. Formula.	H. and A. Formula.	D. and B. Formula	H. and A. Formula.
		Ft.						
1	193·968	72·0	0·0000205	5·929	4·047	5·891	+1·882	+0·038
2	195·349	72·4	0·0000171	5·887	3·710	5·644	+2·177	+0·243
3	180·968	73·6	0·0000034	4·034	1·671	3·775	+2·363	+0·259
4	183·663	74·4	0·0000038	3·977	1·781	3·911	+2·196	+0·066
5	148·042	65·9	0·0000680	6·957	7·044	7·766	−0·087	−0·809
6	178·137	64·1	0·0000638	6·949	6·710	7·409	+0·239	−0·460
7	179·502	64·5	0·0000436	6 825	5·570	6·754	+1·255	+0·071
8	78·828	31·2	0·0000223	3·523	2·681	3·920	+0·842	−0·397
9	134·942	52·1	0·0000303	3·558	4·140	5·515	+1·418	+0·043
10	150·354	57·4	0·0000481	6·319	5·495	6·517	+0·824	−0·198

Noticing, first, the relation of the inclination to the velocity in Nos. 1 and 2, the slope is 205 and 171—omitting the cyphers,—with a velocity of nearly six feet per second; while in 3 and 4 it is only 34 and 38, or one-fifth or sixth of the former, the velocity being about four feet per second, or two-thirds of the former, with nearly the same cross section. Again, in No. 6 the inclination is 638, with a velocity of about seven feet per second; while in 7 the velocity is nearly the same, but the inclination is only about two-thirds that of No. 6, the cross sections being nearly equal.

We also see that the D. and B. formula gives the velocity of that great river correctly when it is 7 feet per second, while at from 4 to 6 feet per second it gives less than half the observed velocity. There

must be some error in these measurements, or the velocity of the water in the Mississippi is dependent upon something besides the fall.

The H. and A. formula agrees, of course, with these observations, as it was based on them. These inclinations were measured by the civil assistants, one of them being re-run five times, and their disagreement is another proof of the small dependence we can place upon the measurement of the fall of a river.

In fact, with the exception of the experimental canals and small streams, there seem to be few if any inclinations recorded which are really trustworthy.

The fall of nine miles of the St. Clair River was very carefully measured, two lines of levels being run on each side of the river, and the surface level obtained at five places on each side. These points were chosen where the velocity was nearly the same, and stakes were simultaneously driven to the water surface, and afterwards connected with the marks on the level lines. There was but little difference between the two determinations, and the mean inclinations are given in Table XVI.

TABLE XVI.

Stations.	American Side.			Canadian Side.		
	Distance.	Fall.	Inclination	Distance.	Fall.	Inclination
	Ft.	Ft.		Ft.	Ft.	
A to B...	9993·5	0·7410	0·00007414	10226·5	0·7253	0·00007092
B to C...	12511·7	0·9805	0·00007839	11867·2	0·6725	0·00005667
C to D...	9695·5	0·8715	0·00008990	11534·0	0·8402	0·00007283
D to E...	17530·7	0·8805	0·00005023	14072·0	0·1775	0·00008369

The stations are lettered the same on both sides of the river, A being below the city of St. Clair, and E near Marysville, and were as nearly opposite each other as suitable places for them could be found.

Between the extreme stations the river runs almost in a straight line, and there are no obstructions except an island between D and E and a shoal opposite St. Clair. Yet the table shows great differences in the slopes, not only between the stations, but also between the opposite sides of the river. For about a mile above the station A, the river remains at nearly the same width and depth; then it widens until it is nearly twice as broad, near the town of St. Clair. Therefore it would seem as if the slope for this whole distance ought to be

rather less than that near station A, where current measurements were made.

But the measured inclination introduced into the mean velocity formulæ gives much too large a result, as will be seen in Table XVII, where the mean velocity is calculated by the different formulæ heretofore given, the smallest inclination, or that on the Canadian side, being used.

TABLE XVII.

Mean Velocity of the St. Clair River, feet per second.

A = 66147 ft. R = 38·06 ft. I = 0·00007092.

Observed.	Calculated by Formulæ.						
	Chezy Co-eff. 80.	Dubuat.	Young.	Eytelwin	Darcy and Bazin.	Hagen	Humphrey and Abbot.
3·272	4·156	4·272	4·490	4·723	5·359	5·510	5·858

Although there is considerable difference in the velocities as computed by the several formulæ, the least value is nearly a foot in a second greater than the observed velocity; therefore the measured inclination must be much larger than its true value at station A, instead of being smaller, as the increase in the cross section near station B ought to make it.

The slope for the whole distance is just about the same as that between stations A and B, except that the larger inclination is on the Canadian side, being 0·000071 there and 0·000070 on the American. As there is scarcely any change in direction in the river, the correction for bends must be very small; and the only apparent cause for a decrease in the velocity below that due to the slope, is the diversion of the current by the island between D and E and the shoal opposite the town of St. Clair.

If the true fall in such a reach of river cannot be measured, every possible care being taken to prevent error, it must certainly be impossible to obtain the inclination of ordinary rivers whose cross section and direction is constantly changing. Therefore, until some better method for the dermination of the fall is discovered, we shall apparently have to be content with the measured velocity, and not attempt to calculate it from the inclination. Surely the velocity determined from a few surface floats could not possibly differ so much from the

true mean velocity as that computed by the best of the preceding formulæ. But, as will hereafter be shown, by means of the telegraphic meter, a very near approximation to the mean velocity can be readily obtained by a few observations.

Among the formulæ given by Humphreys and Abbot is what they call the "mid-depth formula," which, if correct, would be very useful. It is as follows: $v_1 = V_1 - {}_1\frac{1}{2}\,(b\ v)$,[4] in which

v_1 = the mean velocity in any division,

V_1 = the mid-depth velocity,

v = the mean velocity of the whole river,

$$b = \frac{1{\cdot}69}{(D + 1{\cdot}5)},$$

D = the depth of the river in each division,

a = the area of each division.

The mid-depth velocities were chosen because the ratio of the velocity at that depth to the mean velocity "is independent of the width and depth of the stream—except for their almost inappreciable effect upon b_1—absolutely independent of the depth of the axis, and from the small numerical value of ${}_1\frac{1}{2}\ b^4$ nearly independent of the mean velocity."

In order to test this formula, the mid-depth velocity in each division of the several rivers where not directly observed was taken from vertical velocity curves, and the mean depth of each division from the cross section profiles. These quantities for the St. Clair River are given in

TABLE XVIII.

Number of Divisions.	D Mean Depth in Division.	V_1 Mid Depth Velocities.	$\frac{b}{(D+1{\cdot}5)^4}$ 1·69	a Partial Areas.	$V_1 \times a$.	$\frac{1}{12}\,bb$.	$\frac{1}{12}\,bb \times a$.
	Ft.						
1a	15·68	1·420	0·4077	1568	2226.5	0·053	84·67
1b	29·04	3·050	0 3058	2904	8857·2	0·046	133·58
2	39·65	3·820	0·2636	7930	30355·5	0·043	340·99
3	43 55	3·975	0·2506	8710	34622·3	0·042	405·82
4	50·03	3·800	0·2348	10060	38228·0	0·040	402·40
5	52·25	3·750	0·2305	10450	38383·8	0·040	418·00
6	47·65	3·417	0·2409	9510	32495·7	0·041	389·91
7	40·77	2·880	0·2509	8155	23486·4	0·042	350·67
8	28·20	2·316	0·3155	5640	13062·3	0·047	265 08
9	15·25	1·118	0·4129	1220	1364·0	0 054	65·00
				66147	223081·7		2856·12

The value of b was found to be 0·1856 for the Mississippi, and it was considered that this value would generally be applicable to all streams over twelve feet in depth; but this table shows its value calculated by the formula is always greater.

In fact, in one of the divisions in another river it was over 0·7. Multiplying the sum of the partial areas by v, we have $661470 + 2856{\cdot}12\ V^{\frac{1}{2}} = 223081{\cdot}7$; therefore $v = 3{\cdot}294$.

In all the observations on these rivers the mean velocity was found at about six-tenths the depth, a fact which has been noticed by many engineers, and Dupuit theoretically placed it at 0·58 depth.

The velocity at six-tenths the depth and the partial areas for the St. Clair are given in

TABLE XIX.

Number of Division.	Velocity at 0·6 Depth.	Area of each Division.	Velocity at 0·6 Depth into Area.
1a	1·390	1568	2179
1b	2·950	2904	8567
2	3·700	7930	29341
3	3·820	8710	33272
4	3·645	10060	36669
5	3·620	10450	37829
6	3·250	9510	30908
7	2·700	8155	22018
8	2·240	5640	12633
9	1·110	1220	1354
Sums.....		66·147	214770

Dividing the sum of the last column by that of the last but one, we have $v = 3{\cdot}247$.

The mean observed velocity was 3·272; obtained by the mid-depth formula 3·294.

Thus the velocity at six-tenths the depth is a little nearer the observed velocity than that calculated by the mid-depth formula.

Probably had the velocities been taken at 0·58 of the depth it would have been still nearer. This, of course, greatly simplifies the calculation, the correction $\frac{1}{12}(b\ v)^{\frac{1}{2}}$ only serving to reduce the mid-depth velocities to about six-tenths the depth.

Therefore this is a still easier method for measuring the discharge of a stream, as it is only necessary to obtain the velocities at several points at six-tenths the depth, and multiply the mean by the area of cross section.

We have seen, by Table XII, that the two straight lines intersecting at six-tenths the depth approximate closely to the observed velocities; if, then, the velocities are measured at three points on the swiftest vertical, namely, at the maximum, at six-tenths the depth, and as near as possible to the bottom, and plotted on a large scale, joining these points by straight lines, we can find the velocity at any desired position on this vertical—very nearly.

MM. Darcy and Bazin and Capt. Boileau have shown that lines drawn through equal velocities assume very nearly the form of the beds, and this was also found to be the case in the observations on the rivers connecting the Great Lakes; therefore, if we draw lines parallel to the bottom and sides through any chosen velocities on the measured vertical, their intersections with any other assumed verticals will give the velocities at the points of crossing, and thus a close approximation to the true velocity of the river can be obtained by only three measurements.

Of course such observations require some such apparatus as the telegraphic meter, for by this the mean velocity for at least half an hour could be obtained at each of the required points.

WOOD-WORKING MACHINERY.

A treatise on its construction and application, with a history of its origin and progress. By J. Richards, M. E.

(Continued from Vol. LXIII. page 24).

As the ruling form in metal work is cylindrical, so we find it in wood work to be rectangular.

In metal work, at least, so far as machine construction goes, the cylindrical form is a sequence of motion, which, being as a rule, rotary, leads to cylindrical sections.

In modern practice the use of wood is confined to what we will term stationary construction. We sometimes see an old-time wooden shaft, or train of wooden gearing in grinding mills; but its time, as a material for the moving parts of machinery, has passed away.

The main reason, however, for what we have termed the ruling form of section, is more due to the nature of the material than to the special uses to which it is applied.

Iron is nearly homogeneons and can be disposed in varied forms, retaining its strength independent of lamination or fibre; while on

the contrary, wood has but little cohesive strength except parallel to its fibre, and we find it in nearly all cases formed in right lines with uniform section, which is, as a rule, rectangular.

There is perhaps no exception to this rule, unless in cases of ornamentation.

Rectangular sections are surrounded by planes, consequently planing is the leading operation in wood conversion, as turning is in metal finishing.

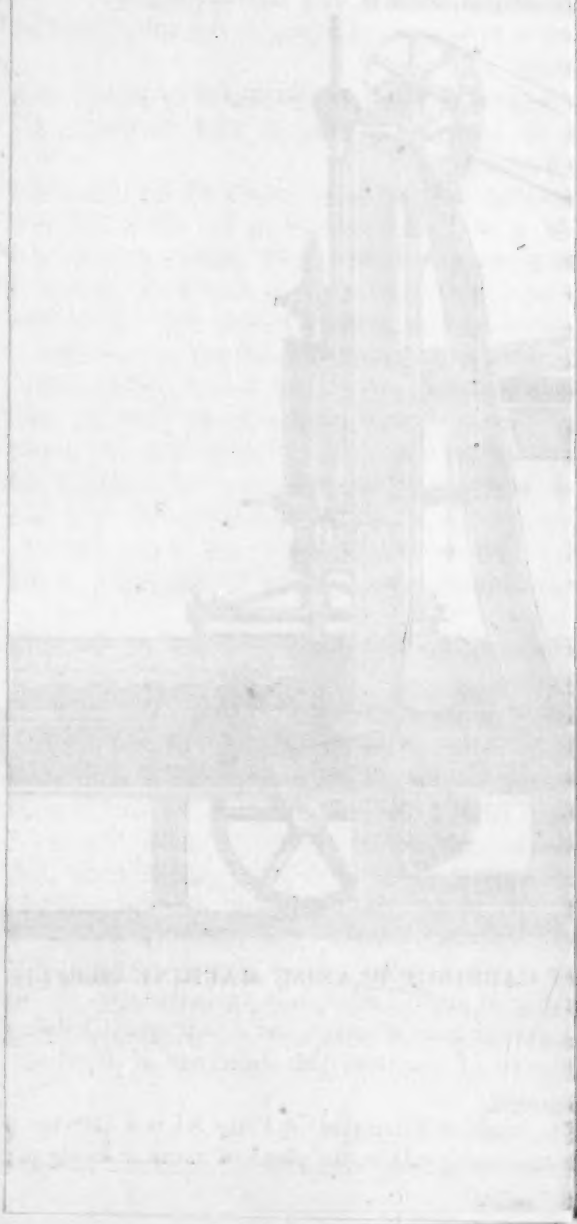
A turning lathe performs nearly all the functions of machine fitting, or is at least capable of it, for the reason that most of the operations are cylindrical; so the planing machine in wood work performs most of the operations in wood work, because the sections are rectangular, and the surfaces planes. This logical method of accounting for what we find already developed in mechanics leads to important improvements, and should indeed qualify every experiment or change that is made or suggested; for their are certain recognized principles of movement, laws of proportion and conditions of operation in machines, which must never be neglected nor lost sight of; their application in special cases is reached by a train of reasoning which we can safely term logical, and if this logic of mechanics was more considered, progress would be more rapid, or at least more safe from error.

The planing machine has been noted as the leading one in wood conversion.

Planing in wood cutting is divided into three classes; in other words, the nature of the operation can be so divided:

Carriage planing—in which the timber is made straight, as well as parallel; parallel planing—by which the lumber is made parallel but not straight, and surface planing—by which there is a constant amount cut away from one or more sides, gauged from the surface of the wood. A proper classification of planing machines would therefore be, carriage, parallel, and surfacing planers, distinctions and names which we trust will be adopted to distinguish them, for the operation of planing wood is, in a popular way, too often regarded as the same thing in all cases, and it is frequently difficult to explain to purchasers of machines this difference of functions and difference of capacity.

The machine illustrated in Plate XI is a carriage planing machine with traversing cutter, the plane of rotation being parallel to the face of the lumber.



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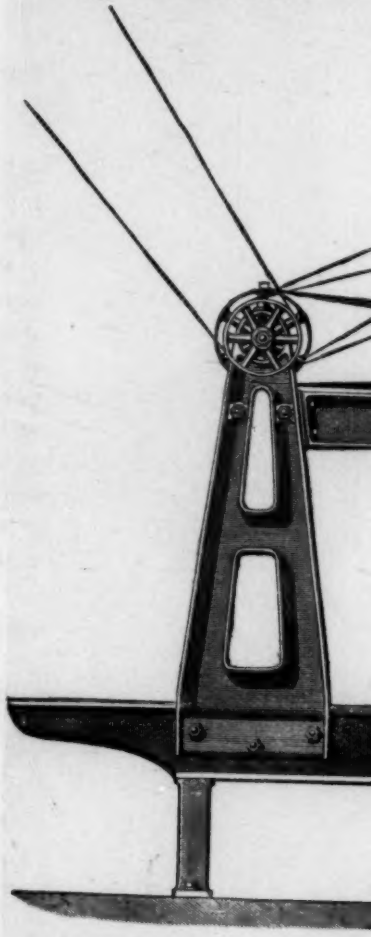
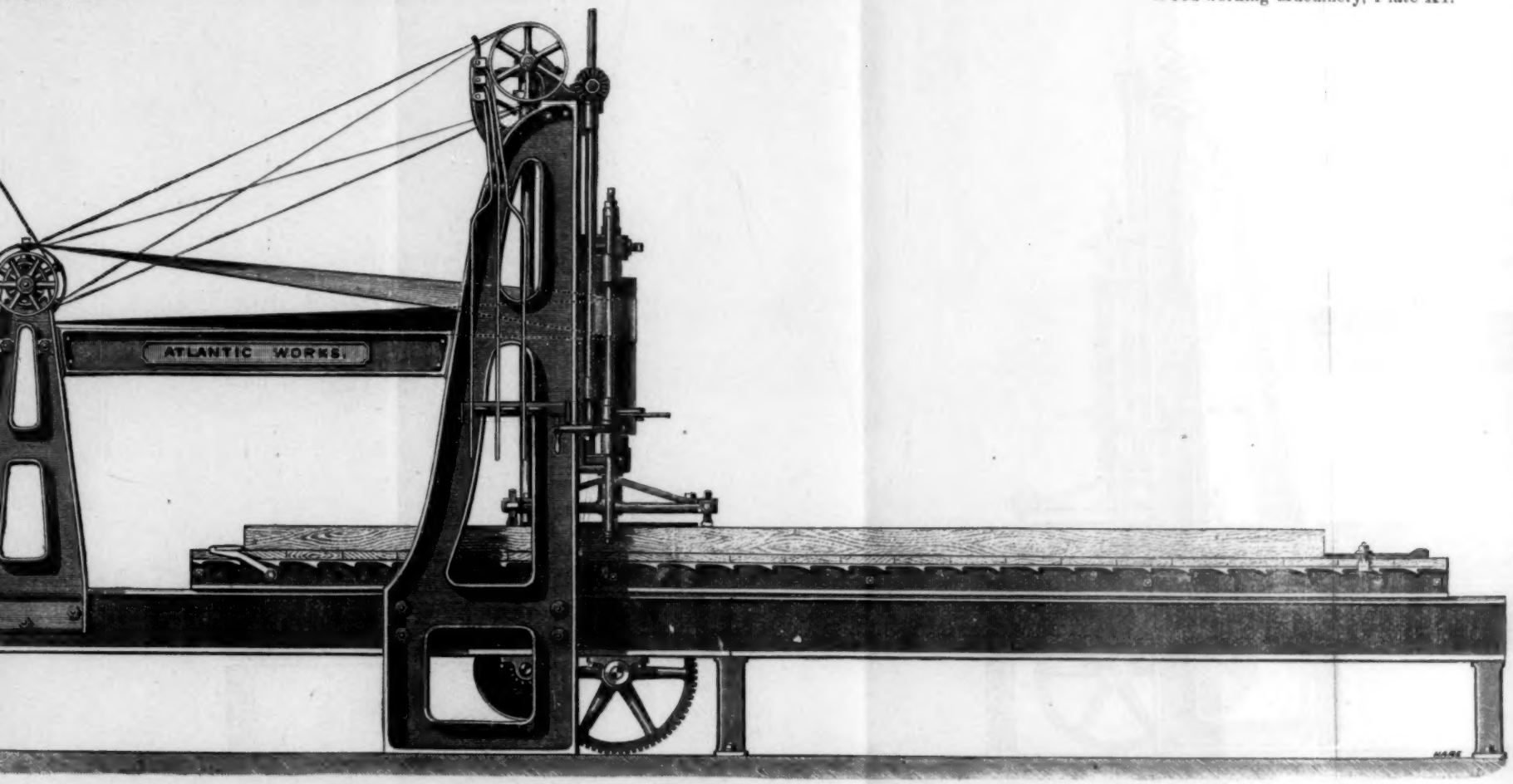
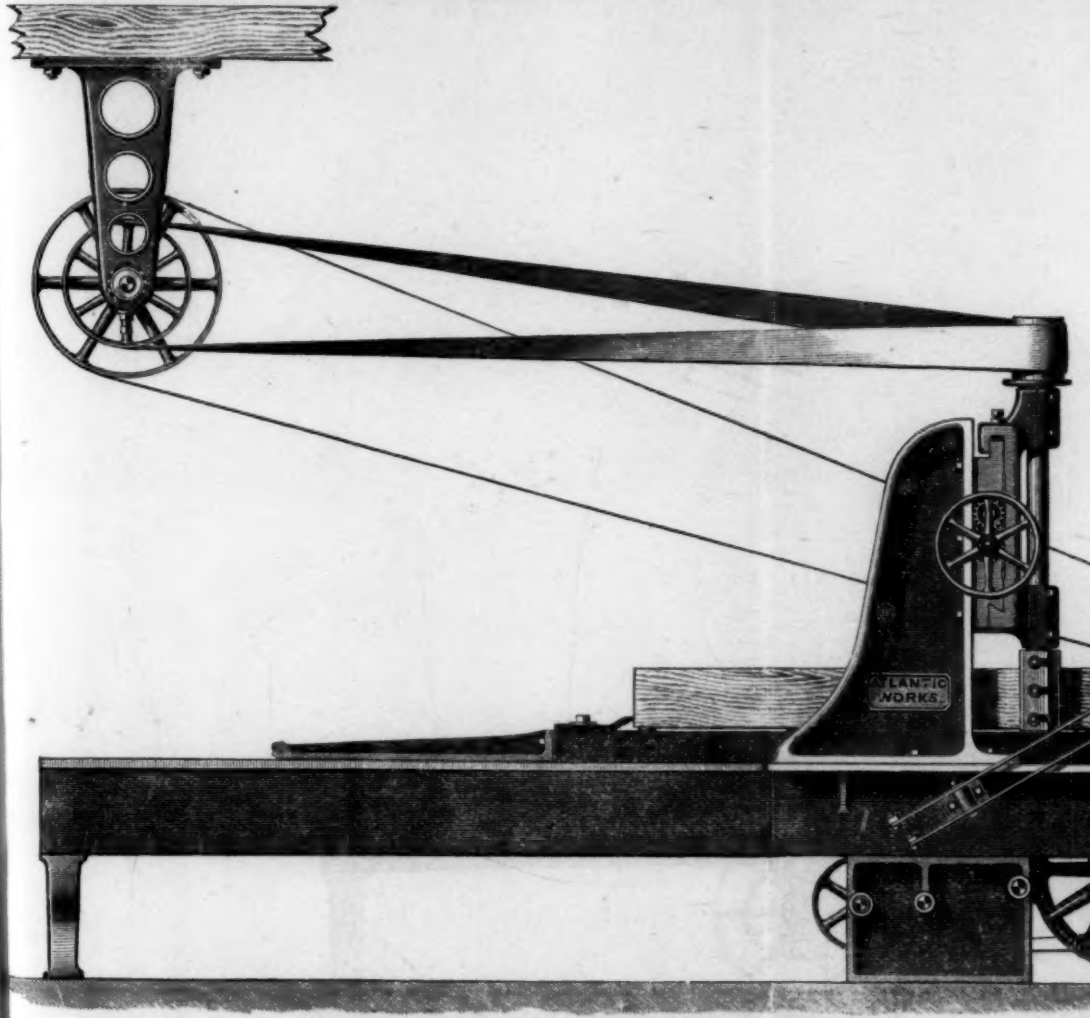
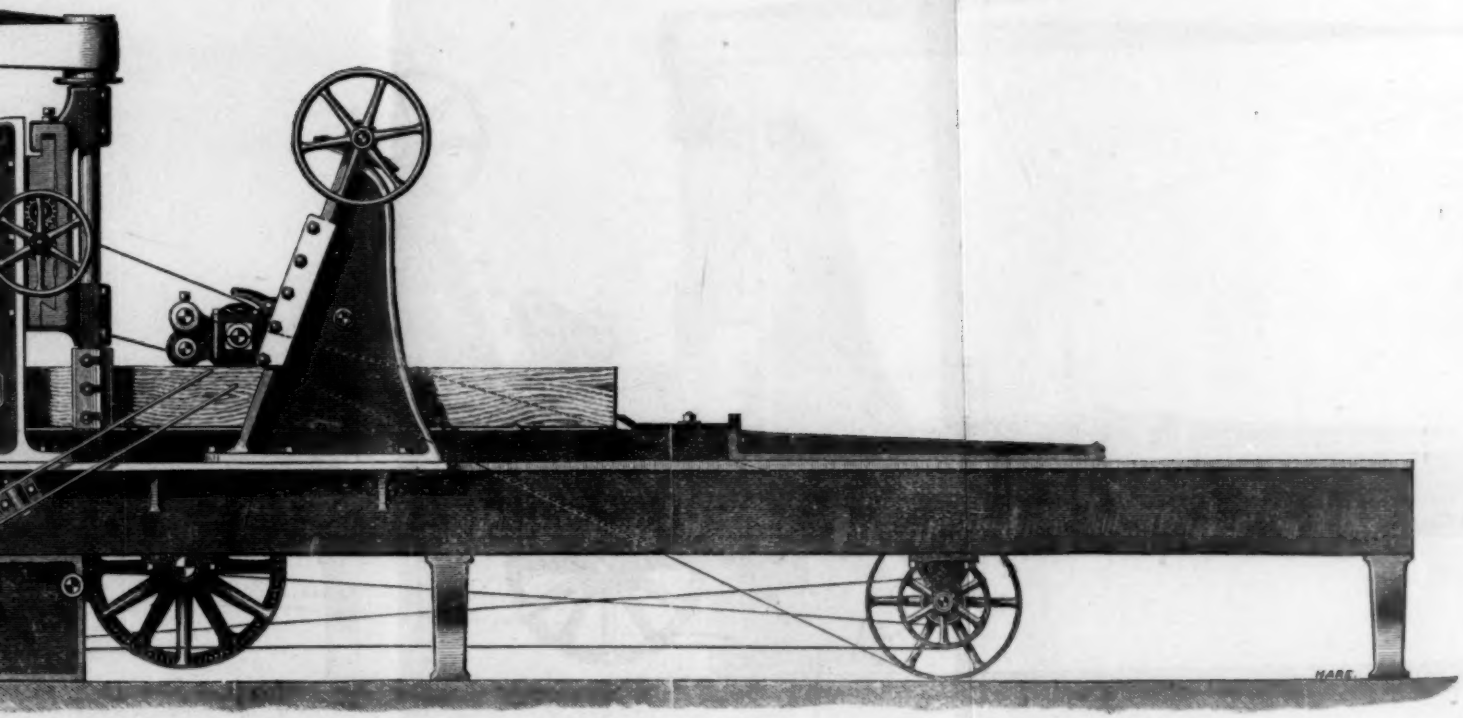




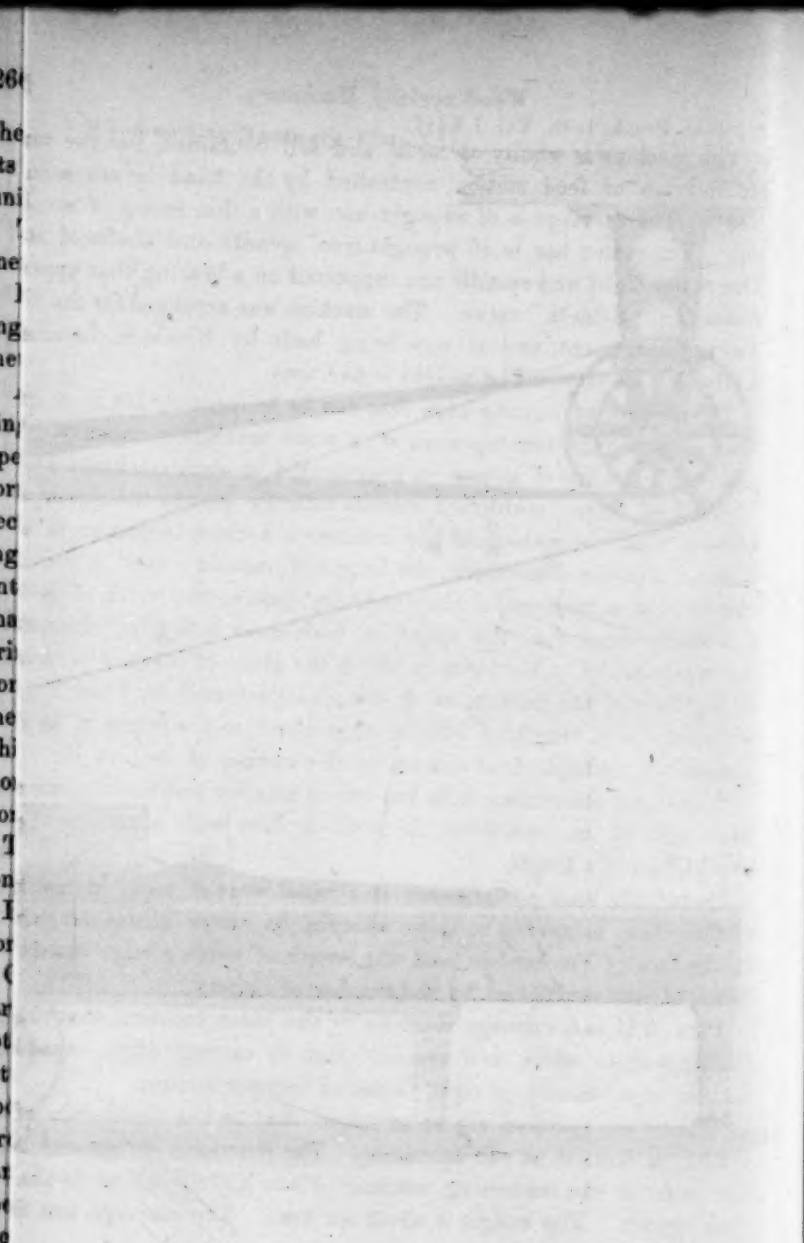
CARRIAGE PLANING MACHINE—Scale $\frac{3}{4}$ inch = 1 foot.



CARRIAGE PLAN



IAGE PLANING MACHINE—Scale, ½ inch = 1 foot.



The machine is wholly of metal and self contained, has the variable degrees of feed motion, controlled by the hand levers seen in front. The carriage is of wrought-iron with a thin facing of wood on top. The cutter bar is of wrought-iron, spindle and shafts of steel. The cutter head and spindle are supported on a bearing that approximates the "Schiele" curve. The machine was arranged for the U. S. Navy Department, and is now being built by Richards, London & Kelly, of this city. The weight is five tons.

The amount of cutting edge that can be brought to act in a given time is, as a rule, the exponent of a wood machine's capacity. The power or capacity of a man is represented in such machines by the "length of edge" multiplied into its velocity, just as the power of a horse becomes the measure of performance in a steam engine, or, to make a more familiar illustration, the length of cutting edges in such machines is as a measure of their capacity, just as the width of belts is a measure of power, the speed in both cases being an element in the computation. Machines in which the plane of rotation is parallel to the face of the lumber, as in the one illustrated in Plate XI, can only employ a length of cutting edge equal to the depth of the displacement, multiplied, of course, by the number of cutters.

Supposing the cutters to be but two in number and the displacement one-fourth of an inch deep, the work is done with a cutting edge of *one-half inch in length.*

Hence the slow performance and rapid wear of tools in machines of this class, compared to those wherein the cutter axis is set parallel to the face of the lumber, and the length of cutting edge equals the width of stuff multiplied by the number of cutters.

Plate XII is a carriage machine by the same builders, carrying in the aggregate *seven and one-half feet* of cutting edge, capable of moving at a velocity of eight thousand feet per minute.

The cutter spindles are so arranged that two or three sides of the lumber is dressed at one operation. The functions in general being the same as the traversing machine (Plate XI) except as to the cutting agents. The weight is about six tons. The carriage and framing is of cast-iron.

It is curious to trace in the history of wood machines, how constant and unvariable has this rule of their efficiency been as the amount of cutting edge. The planing machine, which of all others uses the most edge, will do the work of 50 to 100 men, while machines for boring, dovetailing, &c., that employ but little edge, gain but little

over hand manipulation. This subject will, however, be resumed in another article, in which hand and machine performances will be contrasted.

STEAM BOILER EXPLOSIONS.

Account of Experiments with Locomotive Engines. By Penna. R. R. Co.

No. I.

In April, 1868, an experiment was made near Altoona, on the Pennsylvania railroad, with locomotive engine No. 101. This engine was built in 1854 by Smith & Perkins, at Alexandria, Virginia; it had a copper fire-box, a grate 57 inches long by 42 inches wide, a combustion chamber 25 inches long and a straight boiler 49 inches diameter, 21 feet 10 inches in extreme length. It had been, on account of its extreme age, condemned to be cut up and rebuilt, but it was thought that something useful in regard to boiler explosions might be learned by experimenting with it, and it was determined to test the question whether low water in a boiler under high steam pressure, and the sudden injection of cold water while the boiler is heated, is or is not the cause of an explosion.

This it was proposed to do by permitting the water, under the influence of an active fire, to get so low as to uncover the crown sheet and allow it to become red hot, and then see what the result of pumping cold water into the boiler would be.

To test this, the engine in question was taken on to a branch road running to a coal mine, in a gorge of the mountain near Kittanning Point. A Richardson safety valve was placed upon the boiler, set, as it was supposed, at 150 pounds pressure to the square inch; a steam fire engine was placed about 1000 feet from the locomotive and connected with it by means of ordinary fire-hose. An extra gauge cock was placed at the level of the top of the crown sheet; a large fire was built in the fire-box, but at 110 lbs. pressure the Richardson valve commenced to blow off steam, showing that it had not been properly adjusted; it was screwed down, but as the result showed, a little too far.

The blow-off cock was then opened, and the water let down to within one inch of the top of the crown sheet, the gauge cock on the level of the crown sheet was opened, the fire-box was closed and the blower turned on. The observers then left the engine and took positions behind trees eighty yards from it, whence, by means of

opera glasses, the pressure and water gauges could be noted, and everything that took place could be seen perfectly.

The steam pressure ran up very rapidly, and it was soon discovered that the safety valve had not been set at the proper pressure, as it did not blow off. In a little over one minute after the last man left the engine, the boiler exploded at 175 lbs. pressure. At the moment of the explosion the crown sheet was covered, for water could plainly be seen coming out of the extra gauge cock before referred to, which had been left open.

The engine was thrown over a bank a distance of some 90 feet from where it had stood; the boiler and outside shell of the fire-box were uninjured; the explosion was caused by the left hand side sheet of the fire-box doubling down, and tearing itself away from the stay bolts; the crown sheet being deprived of its support on that side, the bolts by which it was stayed to the roof gave way, and it hinged down, so to speak, and rested against the opposite side sheet.

The side sheets were of copper five-sixteenths of an inch thick, the crown sheet was uninjured. The mistake in the setting of the safety valve prevented the completion of the experiment which it was intended to make, namely, to pump cold water into a boiler in which the crown sheet was uncovered and heated red hot, but by the result the fact would seem to have been demonstrated that no more mysterious agency is required to explode a locomotive boiler than bad construction, or excessive pressure or both combined.

No. 2.

October 7th, 1868. An experiment was made with locomotive engine No. 17, near Kittanning Point, to try the effect of pumping cold water into a boiler with a red hot crown sheet. The safety valve was set at 120 lbs., and the engine was fired up at 8 o'clock A. M.; at 10 o'clock there was a pressure of 40 lbs. per square inch; the blower was then opened, and at 90 lbs. pressure water came out of the gauge cock one inch above the level of the crown sheet. The observers then left the engine and took positions in a place of safety, and with opera glasses watched for the result. In about twenty minutes steam issued from the gauge cock mentioned above; it and another cock two inches below the crown sheet having been left open; but in a short time it ceased coming from the upper cock which probably became stopped up.

In about half an hour more, dry steam issued from the gauge cock two inches below the crown sheet, and then cold water was pumped

into the boiler by a steam fire engine; immediately steam issued from the upper gauge cock which had been supposed to be stopped, the pumping was continued until water came from both the gauge cocks referred to, and was then stopped.

The boiler was then examined and found to have received no apparent injury. The fire was made up again and the observers again sought a place of safety. Steam soon commenced blowing off at the safety valve and blew off continuously for about fifteen minutes, and then blew off intermittently. Steam came out of the lower gauge cock and blue steam from the safety valve; in about fifteen minutes more, it being evident that the crown sheet must be very hot, water was again pumped into the boiler, the result being that the pressure was at once reduced, and on examination the stay bolts were found to be leaking, and the crown sheet was burned and slightly bulged. The temperature of the water which was pumped in was about 60°.

The Manufactures of Philadelphia.—The recent corrected report of the Census Committee contains information upon the subject of the manufactures of this city, which is of national more than of local interest, inasmuch as it presents the vast industrial wealth of the chief manufacturing city of this country in such a form that its true magnitude may be patent to all.

From these statistics, which have been introduced into the national census report, it appears that the whole number of manufacturing establishments in the city of Philadelphia, for the year ending June, 1870, was 8,339. The amount of capital employed was $185,000,357. The number of men employed, 92,112; of women, 38,478; of youths under sixteen, 10,286; wages, $61,948,874. The value of materials operated on was $181,261,223; and that of the finished products, $334,852,458. If to this last figure is added the productions of a number of manufacturing towns in the vicinity of Philadelphia, dependent upon this city for capital and labor, the sum total of the manufactured products for the year foots up $362,484,698; a sum which the Committee observe is over fifty millions of dollars greater than the entire import trade of our commercial metropolis, and one hundred millions greater than its entire export trade.

Chemistry, Physics, Technology, etc.

ON THE PRINCIPLES OF GUN CONSTRUCTION.*

By Lieut. C. E. Dutton,
U. S. Ordinance Corps.

In the first lecture were discussed the principles involved in the construction of projectiles, and the work to be done by them; in the second, the moving agent, gunpowder, was treated of. Let us now proceed to examine cursorily the difficulties to be overcome by a gun in controlling this agent. We may consider the gun as a hollow cylinder, exposed to the action of an elastic force in the bore. If the metal of which it is made was perfectly rigid, *i. e.*, if it were not susceptible of expanding under tension, or contracting under compression, the problem would be very easy, for in that case the strength of the cylinder would, if perfectly homogeneous, be directly proportional to the thickness of the walls; for the rigidity (being supposed to be absolutely perfect) would bring into play the cohesion of every part equally throughout the walls, and consequently the thicker they were, in just that proportion would they resist. But in reality no metal is perfectly rigid, and all gun metals have two kinds of elasticity. If they are subject to tension, within certain limits, they stretch; and when the tension is released, they come back sensibly to their original dimensions. If, also, they are subject to compression, they diminish in the direction of the pressure, but restore themselves when the pressure is removed. Let us see how these elasticities operate in the hollow cylinder. Conceive this cylinder to consist of a great number of concentric cylinders of small thickness. It is the inside cylinder which receives the outward stress of the forces, and it tends to stretch in the direction of its circumference, and to become thinner in the direction of its radius, being pressed between the gases on the inside and the next ring on the outside. The result is that it increases its diameter and diminishes its thickness. Let us, for the moment, drop the elasticity with respect to compression, and consider by itself the extensibility. We see the first action of the inner ring is to expand. By so doing it will communicate an outward

*The following paper is one of a course of lectures delivered before the Franklin Institute at Philadelphia, in January and February, 1872. Revised for publication.

pressure to the next ring, which will also expand, pressing outward the third, and so on to the last. Suppose, at first, that the metal is extensible but incompressible, all the rings would then be stretched, and their diameters and circumferences increased. They would all be increased too by an equal amount. But the interior circles are smaller than the exterior ones at the outset, and though the circles have all stretched the same amount *absolutely*, yet the interior ones have stretched more *proportionally*. Assume, if you please, that the diagram represents a cylinder with a calibre of one foot, and with walls a foot thick. Then the outer circle is three times the circumference of the inner. Suppose the inner circle has been stretched a tenth of an inch; if the metal does not compress, then the outer circle has stretched a tenth of an inch also. But it is clear that a tenth of an inch is a larger proportion of the circumference of the inner circle than it is of the outer one; and in fact the stretch of the inner circle is three times as great, per lineal foot, as that of the outer. Hence, when the inner circle had reached its elastic limit, the outer circle would be only one-third of the way to that point. Now the amount of stretch measures pretty nearly the amount of strain, and the amount of strain measures in turn the amount of *re*-strain, which any circle exercises. As the outer circle is three times as far from the common centre as the inner, and its restraining influence is only one-third as great, we conclude that the restraining influence of this ring is inversely as its distance from the centre, when the metal is incompressible.

Let us now introduce the effect of compressibility. In the first supposition, the expansion of the inner ring pushed out all the rings outside of it, increasing their diameters exactly as much as it did its own. But if the rings had been made each a very little thinner at the same time, it is clear that the increase of diameter would be less and less in each succeeding circle from the inner one outwards. Hence, the amount of stretch in the outer rings is still further diminished by the introduction of this second elasticity, which tends, just as the other one did, to diminish the restraining influence of the outer circles. The effect of this is to bring the inner portion of the wall of the cylinder up to the point of rupture before the outer portions have exerted more than a small part of their real strength, and when rupture takes place it does so in detail—the inner part breaking first, while the outer parts are barely exerting themselves. To follow out the law by which the restraint of different portions of the wall is ex-

ercised is a profound application of the higher calculus, which has no place in a lecture.

It is sufficient for us to know that, in the strength of a gun, the restraint of the outer parts becomes very rapidly less as the diameter of the exterior increases, and that we add little to the strength of a gun by increasing its thickness beyond a certain point. But although we may not here enter into an analysis of the ratios of these properties, we may give them a general discussion, which will present them in a tolerably appreciable manner.

The properties of metals for guns, which are of importance, are quite numerous. Inexperienced, or I may say, inexpert thinkers on this subject are in the habit of paying attention to a single property, viz., tenacity. It is a common impression that what are usually termed "strong" metals can alone be recommended for this purpose. When we come to sift the meaning of the term "strong" we find that it means tenacious, and the standard of tenacity is established by taking a short specimen of it, putting it into a testing machine, and pulling it asunder with a measured force. I propose to discuss this property further on, and will merely say here that, other things being equal, a highly tenacious metal is better than a less tenacious one. But the discussion just given of the hollow cylinder makes it evident, I trust, that other properties are equally important. Let us enumerate some of them:

1. *The tenacity within the elastic limit.*—It is necessary to distinguish clearly between the power to endure extension, and resume the original shape afterwards, and the ultimate stress which a metal can endure. It is generally held in gunnery, that if the stress be greater than the limit of resilience the rapid degradation of the gun is sure to follow, and the only value attached to the excess of tenacity lying between the limit of ultimate resilience and ultimate tenacity is to make the destruction progressive instead of immediate. Yet this is no doubt a most valuable property; for by watching the enlargement of the bore of the gun, we can form a very good idea of how much it has been degraded by firing, and how much of its endurance has been expended.

2. *Hardness.*—This quality is of great importance for two or three totally distinct reasons. The first one will be seen when we consider what has been said of the expansion of hollow cylinders by internal force. Take the case of a cylinder having a given tenacity but inferior hardness, and compare it with that of a cylinder of the

same size and the same tenacity, but harder. It is clear that the one of harder metal will, for a given amount of expansion in the inner ring, push the outer rings farther away and stretch them more, thus bringing the strength of the outer portions more forcibly into co-operation with the inner portions. Hence the harder cylinder would be stronger than the softer, although the tenacity of the two metals might be identical. Hardness is also necessary to prevent the bruising or hammering of the projectile. A soft metal is quickly indented and the bore battered out of shape, by the balloting of the shot when spherical projectiles are used, and in case of rifle shot the sharpness of the lunds is soon worn off and the rifling destroyed. Still again, hardness is essential to prevent the guttering or channeling produced by the action of the gases of inflamed gunpowder. Soft metals are acted upon most destructively in this way, and deep channels are quickly worn in the bore and around the vent. Hard metals, too, are more or less affected in the same way, but much more slowly than soft ones.

3. *Extensibility* is the degree to which a body can be stretched; it is usually considered only so far as it lies within the limit of resilience. It appears that the metal which is most extensible (without permanent set), other things being equal, is to be preferred, since it brings the outer parts more effectively into co operation with the inner.

4. *Elasticity with respect to tension* must be clearly distinguished from the foregoing property. By elasticity is meant a certain power of resistance to the action of a force, and in this case it is measured by the ratio between the amount of stretch and the force required to produce it.

5. *The elasticity with respect to compression* is always important. By this is meant the ratio between the amount of compression and the force producing it. The metal should be as nearly incompressible as possible, for the more compressible it is the less is the strain thrown upon the exterior portions and the more upon the inner.

It appears, then, that the properties which enter into a good gun metal are numerous and complex. But complexity would give the scientific gun-maker very little trouble were the properties all as plain and intelligible as those mentioned, for the mathematician does not stop at complexities; give him the facts and the laws, and he will quickly find a solution. Unfortunately there are other qualities in-

herent in and peculiar to metals, which escape satisfactory analysis, and which sometimes show their existence in the most disastrous manner. The bursting of a gun is always a most serious matter; but, to the ordnance officer, the most formidable and deplorable circumstance connected with such mishaps is that they often occur when least expected, and from causes not understood. If we knew those causes accurately, we could very probably avail ourselves of the resources of modern metallurgy and devise a remedy; but we too often find ourselves like physicians in the midst of diseases unknown to our pathology, and merely know that our tonics are powerless. Take an instance:

A steel axle, turned with a sharp "shoulder," is almost sure to break at the smallest provocation, and nearly every mechanic may be able to recall instances where pieces of steel with shoulders have actually seemed to be shaken in two by a jar or shock which would have given no inconvenience to a piece of wrought iron or even cast iron; and every lathe hand understands well the importance of rounding the reëntrant angles of a steel forging. In explanation of this mode of breaking, it has been suggested that the differences in the pitch of vibration of the parts on either side of the shoulder causes an interference of the waves at that point. But let any man try to conceive how this can produce rupture and he will find himself as much puzzled as ever.

Still again: Some years ago an experimental boiler for one of our naval vessels was constructed of steel. During the process of riveting, a plate was found to have cracked through from top to bottom. A fragment of this plate was afterwards folded and refolded *quarto*, and the folds hammered down cold, without a sign of a crack anywhere about it.

Now, we call this peculiar behavior brittleness, and yet no man has ever explained this property, or told us how it comes about that a material which is strong in the presence of one force is miserably weak in the presence of another. No man has been able to measure it and give us such an insight into its operation that we can calculate its effects upon the resistance of the material which it inheres. There is some property similar to brittleness in gun metals, and that, too, in some gun metals which do not exhibit it sensibly in those forms and under those forces in which they usually are employed in the arts. Its operation will become clearer when we treat of the metals possessing this mysterious property.

The metals employed in gun-making may be confined for this lecture to three: (1) cast iron, (2) wrought iron, (3) steel.

I. The popular idea of cast iron is that of a weak, brittle, hard, and generally vulgar and contemptible material, very good for anvil blocks, stoves, engine bedplates, pots and kettles, and for any purpose where weight and stability are required, but out of the question when strength is demanded. I do not wonder that this is the popular idea. The iron in ordinary use is just about fit for anvil blocks, and pots and kettles, and so far as strength is concerned is as bad as human ingenuity can make it. How many iron founders in Philadelphia today, excepting possibly the car-wheel makers, and roll makers, and one or two kindred trades, where must be used strong iron, have ever troubled themselves to inquire whether the iron they use is strong or weak? So long as it fills the mould well and is cheap they are satisfied. The great demand is for an iron which will fill well a greensand mould and melt rapidly in a cupola. But it happens that these very properties of great fluidity, soundness and fusibility, are engendered by the presence of foreign elements, which deprive it of strength, toughness and elasticity. Take phosphorus, and silicon, and the metals aluminium, calcium, sodium—you find the largest quantities of them in those irons which make the best castings. The fame of the Berlin castings is world wide—castings which will reproduce in metal the figures of a damask napkin or point lace; the property which enables the metal to receive these imprints and retain them is due to the presence of an abnormal quantity of phosphorus, calcium and silicon, and the metal is as brittle as glass and slightly stronger than a brickbat. Scotch pig is used in the arts on the same principle as proof spirit is used in trade. Too utterly abominable to be used by itself, it is employed to "rectify" other irons, and the fluidity and soundness of castings when Scotch pig is used is due to the fact that this brand carries with it about one to three per cent. of phosphorus, and an unusual percentage of other impurities. But I wish to convey in the strongest and most emphatic manner the impression that the iron now used in the manufacture of cast iron guns is separated by a very wide interval from the cast iron of the trades. To contrast the popular idea of cast iron with the ordnance idea of it I will state that Mr. Anderson, the former Assistant Superintendent of the Royal gun factories at Woolwich, a few years ago, in a paper on the subject of gun construction, spoke of cast iron as a metal having an average tenacity of 14,000 lbs. per square inch, and applying

the ordinary factor of safety (5), said that it could be relied upon for a stress of about 3000 or 4000 lbs. per square inch. Now the standard of tenacity of our ordnance irons is between 36,000 and 40,000 lbs. per square inch, and we do not hesitate to work them up to three-fourths of their ultimate tenacity, or say 27,000 to 30,000 lbs. per square inch, which is just about eight or nine times as high as Mr. Anderson put it. We have done this practically for the last ten years, and have not burst a solitary gun, except in cases where we knew we had exceeded the ultimate possibilities of the metal.

The selection of ores is confined to those which are most easily reduced. They must also be very free from phosphorus and sulphur, and must be acted upon at a low temperature in the smelting furnace. Those hitherto in most favor are the limonites of that series to which the Salisbury, Copake, Tyrone, Sligo and Bloomfield beds belong. As these ores contain considerable alumina and silica, they require but a small addition of lime to make a very fusible flux, which admits of their being smelted in a charcoal furnace of small size, and with a cold blast. The low temperature of smelting enables these ores to reduce with only a small quantity of silicon and earthy bases, and a high percentage of carbon. The iron thus smelted is subjected to repeated fusions in an air furnace, and each successive fusion removes a considerable proportion of the silicon and carbon. The carbon is kept up by adding to each result some pigs containing the highest percentage of that element, and the final casting is made from irons containing a very low percentage of silicon and a moderate quantity of carbon, and as free from other impurities as it is possible for any cast iron to be. The resulting gun metal is chemically not far removed from steel, and its mechanical properties approach those of a sand-cast steel ingot. The only limit to this process of refinement is the possibility of keeping the metal sufficiently fluid to cast well. As cast iron parts with its impurities its fusion point is raised, and at last becomes so high that the reverbatory furnace can no longer keep it fluid, and it solidifies into a spongy mass, which is wrought iron or semi-steel. Hence, in the use of an air furnace the iron must not be refined so far as to become viscous, for it must retain sufficient fluidity to pour and cast thoroughly well, otherwise the casting will be porous and honey-combed. The metal of our cast iron guns is tenacious, very hard, elastic under tension, and very moderately so under compression, and possesses in a high degree the properties essential to a good gun metal. Its tenacity up to the limit of permanent set is much

less than that of steel, and its hardness is decidedly greater than the soft steels used for guns, while its extensibility is less. It is more incompressible than the low steels used for gun-making, and far more so than wrought iron. In a comparison of the products of these properties the theoretical advantages are in favor of steel, but not so overwhelmingly as might be thought if we judged the two by merely comparing their tenacities, for the superior hardness and incompressibility of cast iron bring into play the outer circles of the hollow cylinder more effectually than in steel; in a word, the restraining influence of the exterior portions is greater proportionally in a cast iron gun than in a steel one of the same dimensions. But on the whole, so far as strength depends upon known conditions, cast iron is inferior to steel, but not in proportion to their respective tenacities. There are some unknown conditions, which may or may not affect the case, which will be alluded to further on. Up to the limit of its strength, as determined by theory and verified by experiment, cast iron is thoroughly to be relied upon, and the long and fruitful experience of our officers with this metal leaves no doubt that every failure may be accounted for by the fact that the guns which have yielded have been overcharged.

Cast-iron appears to be suitable only for smooth-bore guns. The increased strain caused by the longer column of metal in firing elongated projectiles renders it more than doubtful whether we shall be able to avail ourselves of this metal in constructing rifled cannon, especially large cannon. Theory indicates that, even at the most moderate pressures of gunpowder, we are verging very near to the limit at which our strongest cast-iron must break, and our experience with large rifles has shown that these pressures are liable to spring up to a destructive point when we least expect it, in which case the gun must rapidly give way.

On the suitableness of wrought-iron for gun metal there has always been much controversy, and even to-day the only advocates of this metal are the English, who differ greatly among themselves on this point. It is now established by proofs of the strongest character that wrought-iron, in the form of coils, is a very superior metal, though a majority of the European gun makers and mechanics consider it much inferior to steel. I shall speak of its record elsewhere, and discuss at present its peculiar properties.

The ultimate tenacity of wrought-iron, as indicated by the ordinary tests known among us as the Kirkaldy tests, is about 50 per cent.

higher than that of our cast-iron. But it possesses a property which pertains only in a small degree to cast-iron, viz., the property of elongating very considerably and permanently under tensions below its ultimate tenacity. We call this property ductility. Although wrought-iron shows measurable and permanent elongations at strains of a few thousand pounds per square inch, it is not usual to treat of them as having any practical value until the strains amount to about 25,000 pounds, at which point the elongations begin to be serious, and increase rapidly up to the breaking limit, at which stress the elongations sometimes reach in very tough iron 20 and even 25 per cent. of the original length. Moreover, repeated applications of the load give increased elongations. In treating of the tenacity of wrought-iron, therefore, we have no right to take as a standard of its useful or working strength the limit of ultimate tenacity, but only that portion which lies within the practical ductile limit—for it will appear that a gun which stretches permanently and to a material extent after every fire will soon become practically useless by the enlargement of the bore at the seat of the charge. This very difficulty occurred in a gun made at Salisbury, Conn., out of the famous iron of that locality, which had enlarged so much after a few fires that it was virtually unserviceable. Although this form of degradation is by no means so objectionable as a liability to burst, yet it is abundantly so to condemn any material in which it cannot be avoided.

Now, if we are to take the Kirkaldy tests as the standard of tenacity, or resisting power of the metal, we should, by strict logic, confine ourselves to the ductile limit as the available and practical measure of strength, and not attempt to reason from its ultimate tenacity. But I do not hesitate to assert that the Kirkaldy tests would thus underrate the value of wrought-iron, and cannot be logically used to base upon them any inferences respecting its suitableness for gun-metal. The break in the logic which would so use them lies in the fact that the stress is applied in the testing machine cannot be compared to that applied by gunpowder. I am not questioning Mr. Kirkaldy at all, whose tests are accurately and intelligently made and reported, but am merely questioning the logic which would use them to infer the utility of wrought-iron as a gun-metal. If these tests could be so used, then we should have to set down the useful limit in the tenacity of wrought-iron at 25,000 pounds per square inch, or say about one-half its ultimate tenacity, the residual half being useful only so far as it allows the gun to bulge instead of burst. But, if

there be any result in the English experience of the last fourteen years more clear than another, it is that this useful limit of wrought-iron tenacity is very considerably higher, although it is probably not up to the ultimate limit. We may, perhaps, find a satisfactory solution of this fact. The ductility of a metal is one case of the phenomenon termed the "flow of solids. The forcing of lead pipe is a striking illustration of another case. But in the flow of solids time is an important element, for the viscosity of the material requires that the particles, whose relative positions are changed, should have time to adjust themselves to the changes induced upon them; and the more powerful the cohesion, the more slowly do they obey the impress of external forces. Hence, when we apply the stress very suddenly and briefly, we find that we do not obtain anything like so great an elongation as when we apply it slowly, because we do not give the particles time to yield to the force and take new cohesions. But it is also probable that, while we find a higher ductile limit with sudden forces, we probably find also a lower ultimate limit of tenacity. The evidence in support of this view is not so abundant as might be desired, but is yet very strong, and I know of none to the contrary; the subject does not seem to have been thoroughly investigated, and consequently evidence in either direction is indirect. But we may safely say that the useful limit of tenacity in wrought iron is considerably higher than the ductile limit assigned by such tests as Mr. Kirkaldy's. Comparing it with cast-iron we have, in the latter metal, no such thing as ductility, and have only the ultimate tenacity to consider. Experience with coil guns seems to warrant the conclusion that the useful tenacity of wrought-iron is a little higher than that of our best cast-iron, but there is no satisfactory proof that it is very much greater.

The foregoing remarks may have some bearing on an objection raised against the Woolwich system of construction by those who advocate the use of steel alone, viz., that after a few fires the wrought-iron coil soon ceases to exercise any restraining influence on the steel tube, being permanently stretched, while the tube is working within its elastic limit. If the useful strength of wrought-iron is as low as the Kirkaldy tests would place it, this hypothesis is not improbable; but if, as I conceive, it be materially higher *in the gun*, its probability is greatly diminished. Yet, if we assume that there is a certain margin of ductility in wrought-iron, even in the gunpowder test, and if the limit of it be considerably lower than the elastic limit of steel, we may still look for this relaxation of the coil when the stress of firing

becomes very great. It would be more likely to occur in large guns than in small ones; but in any case the considerations advanced seem to modify greatly the force of this objection to the Woolwich system, which has certainly demonstrated the efficiency of wrought-iron as a gun-metal most satisfactorily.

We have always associated with steel the ideas of strength, endurance, hardness and homogeneity, in their perfection, and it is quite natural that the gun-maker should look to this metal as the one better suited than all others to restrain the terrible forces he is compelled to use. If we take its resistance to strains as indicated by such tests as Mr. Kirkaldy's, we shall be led to infer that the useful strength of steel is more than double that of wrought-iron, and about three times as great as that of cast-iron. Unfortunately our whole reasoning respecting this metal is based on the breakages of innumerable specimens of less than a square inch of cross-section. Treatises on the strength of materials assume that the resistances afforded by these small specimens are units, or constants, by which the strength of a mass of any size and any geometrical figure may be measured. But do facts sustain this reasoning? Do they show that a large mass of metal really possesses as much strength per unit of cross-section as a small test specimen? It may seem to be a singular question to propound at this late day, whether the whole basis upon which that branch of mechanics known as "strength of materials" rests, is really a sound one; whether all the mathematicians and mechanics who have discussed the subject have not overlooked a very obvious consideration of a vital character. But let us examine the matter a little. Is there in the whole range of experiment on the strength of metals a well authenticated instance (excepting certain ones which will be alluded to), where a large mass of wrought-iron or steel has been subjected to trial, to test empirically the question whether a large mass is really as strong per unit of cross-section as a small one? Certainly no known treatise and no adopted formula or theory recognizes any such ideas to the contrary. What are the English Admiralty tests? what kind of tests have been adopted as standard by the French *Conservatoire des Arts et Metiers?* by the Swedish, Russian and Prussian Governments? Every one of them adopts as standard units the results given by the extreme proof of specimens having a section of about a square inch, and in some cases less. From these the strength of a larger mass is always deduced by a purely theoretical formula. The only apparent qualification to this state-

ment of the case is the use of a factor of safety, which means that, in practice, a piece of metal in a large structure is not to be relied upon to give a resistance to strain in excess of one-fifth of this calculated strength. But is it not most extraordinary that, after an elaborate calculation, we are obliged to throw away arbitrarily four-fifths of our result as being probable error, and keep only one-fifth? We may very properly allow something for weak spots, imperfect workmanship, &c., something also for the "fatigue" of the metal; but surely no man would think of thus disposing of four-fifths of the strength he calculates upon, had he not before him the unanswerable fact that numerous structures, in which a smaller factor of safety has been used, have collapsed.

If we take the case of a rod, subject to a simple tensile stress, it certainly seems a fair inference that ten square inches cross-section ought to withstand ten times as much as one square inch, with a small deduction for assumed lack of homogeneity. A few months ago, Mr. James B. Eads determined to test this question—for such he deemed it. In a huge machine, constructed for the purpose, he caused to be placed some long steel anchor-bolts, 5¾ inches diameter, and the first four snapped at strains averaging about 30,000 lbs. per square inch, while a number of small samples (three-quarter inch section), taken from the crop-ends of the bolts, all endured upwards of 100,000 lbs. per square inch without a single failure.* It would certainly be unwise to undertake to prove a new view of the strength of materials from a single series of experiments. But this does not fairly state the case. There are several considerations of great moment which are applicable at this juncture. First, it must be remembered, that no experiments with large masses have been made and put on record (at least, so far as is known to me), with a view to test this matter, excepting the one first alluded to. Second, many striking cases may be cited to illustrate the belief that large forgings of steel often fail to exhibit, from some unexplained cause, the strength indicated by test specimens. It would be impossible to give a clearer illustration of this than by quoting the record of solid-forged steel guns.

* Having witnessed the forging and testing of these bolts, and taking particular interest in the matter, I cannot soon forget the astonishment felt by all who saw these failures. It seemed to be quite inexplicable. Some attributed it to internal strains, and another lot of rods was annealed, but with results no better than before. Taken in connection with the extreme care and accuracy of the whole trial, the whole matter became extremely perplexing, nor is there any apparent way of explaining it without resort to conjectures not usually entertained by engineers.

LECTURES ON VENTILATION.

Delivered before the Franklin Institute.

By L. W. Leeds, Esq.

(Continued from page 216.)

We have here a diagram, prepared at the request of some gentlemen of his city,* showing some suggested modifications of the ventilation and warming of the Hall of Representatives. It is proposed to draw off the foul air both at the top and bottom.

That taken from the bottom is to be drawn through the present inlet registers, and that from the top to escape around the sides of the glass as at present, and through the illuminating loft to the external air.

Now, with a little ignorance or carelessness it would be very likely to be so arranged that discharging the air in two opposite directions might make confusion, and that it would, at times, all draw up, and the foul air, instead of escaping at the floor, would flow in there; and at other times it would escape at the floor and come in at the ceiling; but it is very easy to avoid such action and with entire certainty.

This is the proper manner to arrange all large buildings intended to be occupied by a considerable number of persons; there should be escapes for foul air thoroughly distributed over the floor, also liberal escapes from the ceiling, and these should be kept constantly open when the room is occupied, and there is no practical difficulty whatever in doing this.

It was originally intended to overflow the hall with the fresh air driven in by the fans; but, practically, this is not the general condition. Several experiments, tried at various times, indicated a strong current setting into the Hall of Representatives from the corridors through every door, both above and below, so that practically the main room is supplied by air from the surrounding passages; we consequently recognize this fact and act accordingly. Arrangements should therefore be made to keep the air in these passages as nearly pure as possible.

It is proposed to warm the floors of the hall slightly in excess of the temperature of the room, say to about 80° or 85°, which would still be below the temperature of the body; and also to have all the exterior walls warmed so that there would be a gentle radiation from all the solid bodies in the room. When we are not losing heat by con-

* Rand, Perkins & Co., of Philadelphia.

duction, from contact with a cold floor, and are receiving radiant heat from all the surrounding walls, instead of parting with the warmth of our bodies to these walls, we can afford to be surrounded with and have the luxury of fresh, cool, invigorating air for breathing.

As the corridors would be largely warmed by radiation, the air in them would be cooler than the indicated temperature; it would, consequently, flow into the hall underneath the air longer contained there.

It is not intended, however, to depend exclusively on the supply of air from the corridors in case the doors should all be intentionally or accidentally closed; there would be an abundant supply of air from portions of the perforated ceiling. In winter arrangements would be made to warm this to the required temperature, but as so considerable a portion of the warmth of the hall would be furnished by direct radiation, it would only be necessary to have this air heated to 50° or 60°; consequently, being slightly heavier, it would easily fall in gentle, well diffused currents, to take the place of the foul air drawn out both above and below.

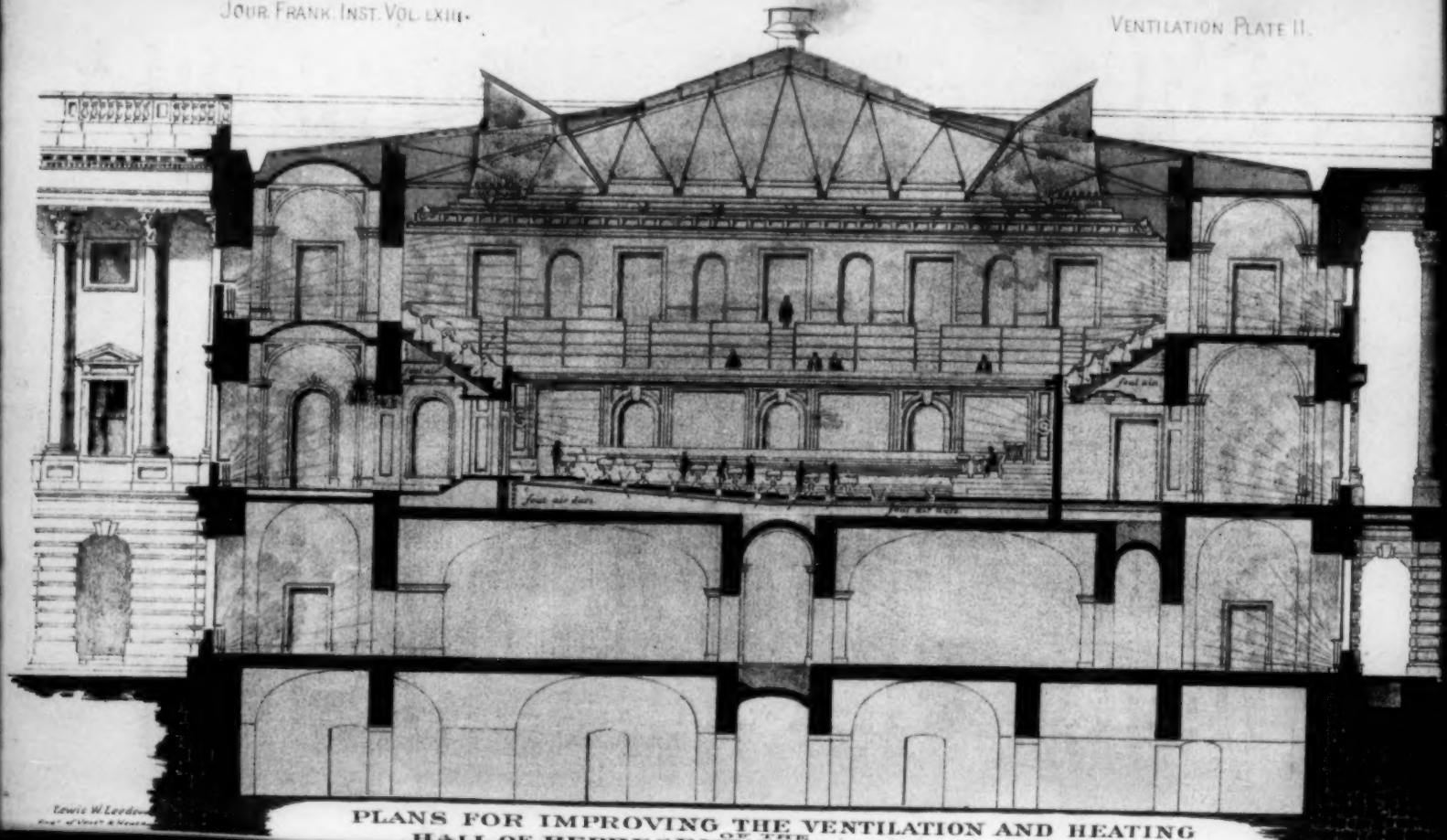
Many persons are afraid of a draught of cold air upon their heads, but if the surrounding conditions are right this is just the position to have it strike the body. For instance: I have stood on the hot plates in front of the boilers in the hold of a steamship, with my back towards the hot boilers, and had a perfect torrent of very cold air falling on the head, which felt delightful.

The firemen are constantly subjected to this without injury, but if they go on deck and stand in a draught, or cool off quickly, *away from the radiant heat*, they frequently take severe colds.

One difficulty about having a cold draught upon your head; it is very apt to be *colder* on the feet, but that part is frequently not noticed.

It is also proposed to put in a row of dormer windows, that would let in more sunlight, and perhaps some of the direct rays of the sun, and in summer would be very useful in catching the breeze as it passed and throwing it directly into the hall as you see here (refer to diagram). It is proposed to entirely disconnect the illuminating loft, so as to avoid the possibility of a returning current of foul air as now occurs; also to make an additional plastered ceiling and a confined air-space to prevent the rapid cooling effect of the exposed copper roof.

It is proposed to dispense with the fans entirely, which I consider



PLANS FOR IMPROVING THE VENTILATION AND HEATING
OF THE
HALL OF REPRESENTATIVES WASHINGTON D.C.

about the greatest nuisances in the building, and rely exclusively on heated shafts.

The same amount of heat applied to a well constructed shaft will probably move a much larger amount of air, at a great deal less cost, and requiring no expensive engineering attendance.

I believe if this plan was carried out it would make a very satisfactory building; perhaps the Hall of Representatives would not be quite equal to a single room, with the walls and floors warmed, and large windows on all four sides for the free admission of air and sunlight, but it would be so much better than many of our public halls, that by comparison it would be considered very good.

The Treasury Building, at Washington, is one of the most substantial and expensive executive buildings in the world, having cost some $5,000,000.

No expense has been spared in any part to make it the most perfect, comfortable,, and convenient building that the ingenuity of man could devise.

I wish you to make a distinction here between the errors of original design and construction, and the troubles resulting from its shameful abuse, because the former show the deficiencies of correct knowledge in this respect among the best informed architects and builders; but the most shocking condition of the old building and ill health of the occupants, as I found them, result very largely from the shameful abuse of it after its completion, and show us the want of general information in the public, which will prevent the very best arrangement that could possibly be made becoming an intolerable nuisance, as was the result here.

It must be remembered that this whole block has been many years in building and reaching its present size. The plans represent it, as now finished, as a single completed building, but we must examine it in parts, according to the ages in which it was built.

The old front on Fifteenth street has been built probably fifty or seventy-five years—quite long enough, at any rate, to show in its original construction those ample old-fashioned fire-places where hickory wood, and plenty of it, was burned in each room.

And when these were in full blast an examination of the absentee list would show a much smaller proportion of excuses for sickness from foul air diseases than at present, with these fire-places carefully boarded up or walled on top, and all the rooms heated from one large central boiler in the cellar.

Most of this part of the building has been remodelled, so as to be heated by radiation from hot water coils in each room, great care having been taken to shut up all crevices to prevent any cold draughts.

The south wing and west wing have been completed much more recently—mostly within ten years. This is the portion of the building which I wish you to examine more carefully.

That cleanly and refined system of murdering human beings, which has spread like a devouring pestilence over our whole land, came into general use about the time this building was designed.

I mean that miserable system of warming our rooms by currents of over-heated, debilitating and ruined air.

At that time I myself was one of its zealous advocates. I had already noticed the universal complaints of the occupants of rooms which were heated by currents of air from the common hot air furnace, but supposed it resulted from some peculiar effect produced by the overheated iron, and consequently went energetically to work to remedy these evils by warming all the air, by bringing it in contact with metal surfaces moderately warmed by circulating hot water.

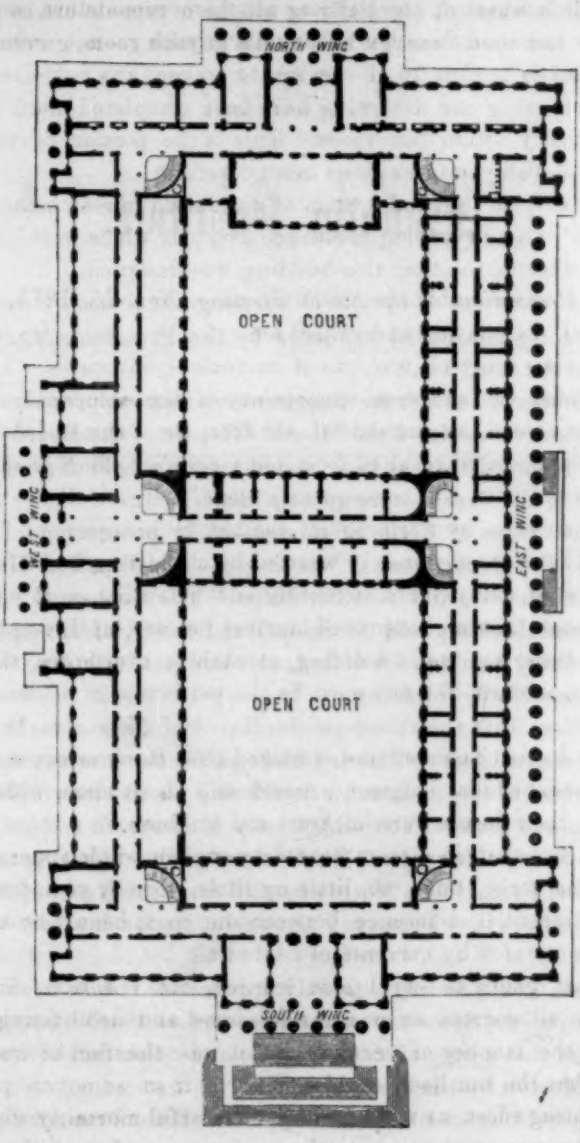
I persevered many years, inventing and patenting in this country and in Europe, new and improved devices for accomplishing this object, fully believing that a building, constantly overflowed with this mild, warm, summer-like air, must be the perfection of artificial heating.

And yet I was chagrined and mortified that many sensible people, with good independent judgment, would still insist upon it that they felt better, their heads were clearer and brighter, in a room heated by an open fire than in a room heated by my hot water apparatus.

It was thus forced upon me, little by little, year by year, that there was a very essential difference between the room heated by an open fire and one warmed by currents of heated air.

I was just going to say I *soon* learned, but I *didn't*. I *slowly* learned that all warmed air was unwholesome and debilitating; that it was not the manner of warming, but it was the fact of its being warmed; that the sun itself could not warm it so as not to produce this debilitating effect, as witnessed by the fearful mortality whenever the air in summer reaches nearly the temperature of the body.

In proportion to my convictions of the unwholesomeness of warmed air did I advocate the introduction of direct radiation—first one-quarter, then one-third and one-half, and perhaps some time I may believe in *heating* by radiation entirely. But there is one practical difficulty



about this, and that is, where the necessary air for ventilation is passed through the room, and it is quite cold, it is so difficult to avoid unpleasant draughts; it requires very careful diffusion.

There are, consequently, fewer complaints of such draughts when